

IN THE DRAWING(S):

The attached sheets of drawings includes changes to Figures 6A, 6B and 6C in which the term “pulse” is replaced with the term “burst.”. These sheets replace the original sheets showing Figures 6A, 6B and 6C.

Attachment: Replacement Sheets

REMARKS

By this Amendment, Figures 6A-6C are replaced with replacement drawings in order to overcome the objection under 37 C.F.R. 1.83(a) and a new Abstract is submitted in conformance with the pertinent requirements. Claims 1-16 are pending.

Claims 1-3, 7-11 and 15-16 were rejected under 35 U.S.C. 112, second paragraph for alleged indefiniteness. Applicant traverses the rejection because one of ordinary skill in the art would readily understand the scope of the claims based on their present wording. However, Applicant also provides the following explanation of the state of Time Division Multiple Access (TDMA) systems for the record to enable the Office to better understand the claimed invention; in particular, Applicant provides an explanation of TDMA time slots and a frame structure for the record.

The pending claims recite the terms "consecutive time slots," "a previous time slot" and "a following time slot." Applicants submit two prior art publications (see attachment), which though not considered to be relevant to the patentability of the pending claims, are relevant to a proper understanding of time slots and frame structure of a TDMA system.

Michel Mouly, Marie-Bernadette Pautet: The GSM System for Mobile Communications, 1992, pages 197-217, ISBN: 2-9507190-0-7, clearly teaches that, in a TDMA system, a frame is often presented as a succession of n time slots, and in a GSM system as the succession of 8 time slots which are numbered from 0 to 7. Frames can further be grouped as multiframes of 26 time slots and superframes which are successions of 51X26 frames.

Further, Siegmund M, Redl, Matthias K. Weber, Malcolm W. Oliphant: An Introduction to GSM, 1995 Artech House, pages 75-77, ISBN: 0-89006-785-6, teaches that, in GSM systems, which are examples of TDMA systems, each frequency channel is subdivided into 8 different time slots numbered from 0 to 7. A set of 8 time slots is referred to as a TDMA frame and all the users of a single frequency share a common frame.

Thus, if a mobile unit is assigned a time slot number 1, it transmits only in that time slot and stays idle for the remaining seven time slots with its transmitters off.

As can be seen in Figure 5.5 of Redl, the same frame structure is also utilized by a base station, which is able to generate 8 time slots for downlink transmissions to mobile units. Regular and periodic switching (on and off) of a transmission of a base station or a mobile is conventionally referred to as "bursting."

Turning to the claimed invention, as explained in Applicant's specification, the invention pertains to a "near-far" problem. Specifically, in cellular radio networks, large radio cells, or macro cells, can be formed so that network operators may cover geographically large areas with a few base stations. The solution is advantageous in sparsely inhabited areas, where traffic is scarce and, therefore, only a few radio channels are needed in each cell. However, a "near-far" problem results when a base station located in a geographically large area receives transmission from both a mobile unit located near the base station and from a mobile unit located far from that base station. A signal arriving far from the base station attenuates along the way and a signal arriving from nearby may efficiently interfere with it.

A worst case scenario occurs if both transmitters employ the same frequency and are placed in adjacent time slots (see, Applicants current application paragraph [0006]). In that scenario, a base station may receive transmissions from a plurality of users, each user transmitting in a time slot allocated to it. The base station would then compare signal strengths of signals received in consecutive time slots, for example, a signal received from a first user in time slot 1 and a signal received from a second user in time slot 2. In that case, the "previous time slot" would be time slot 1.

In that example, the base station would then compare signal strengths of time slots 2 and 3; thus, the "following time slot" would be time slot 3. Thus, time slot 2 would simply be "a time slot".

Applicant also submits a portion of the GSM specification describing time slots and frames, as understood by one of ordinary skill in the art.

Applicant submits that one of ordinary skill in the art would readily ascertain the meaning of the terms "consecutive time slots," "a previous time slot," "a following time slot" and "a time slot" based on the teachings of Applicant's specification, e.g., equations describing the determination of weighting coefficients in paragraphs [0023] to [0025] of specification. In the example:

SR_p represents the strength of the signal received at a base station in a previous time slot,

SR_c represents the strength of the signal received at a base station in the time slot to be detected ("a time slot"), and

SR_f represents the strength of the signal received at a base station in a subsequently received time slot ("a following time slot").

As can be seen, "a time slot" represents a time slot in a TDMA frame and "a previous time slot" is a time slot received before "a time slot;" similarly, "a following time slot" is a time slot received after "a time slot." Thus, the ordinal number of "a time slot" in a frame naturally varies from case to case.

Therefore, Applicant submits that the claims, when read in light of the specification clearly and definitely define the claimed invention in such a way that one of ordinary skill in the art would readily recognize the scope of the claimed invention. No figures need illustrate a TDMA frame because it is part of prior art, and thus, conventionally known by a person skilled in the art.

Accordingly, Applicant requests withdrawal of the rejection under 112 and allowance of the application with all pending claims.

All objections and rejections having been addressed, Applicant requests issuance of a Notice of Allowance indicating the allowability of the pending claims. However, if anything further is necessary to place the application in condition for allowance, Applicant requests that the Examiner telephone Applicant's undersigned representative at the telephone number listed below.

Please charge any fees associated with the submission of this paper to Deposit Account Number 033975. The Commissioner for Patents is also authorized to credit any over payments to the above-referenced Deposit Account.

Respectfully submitted,

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AN INTRODUCTION TO GSM

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Mobile Communications in the U.S. and Europe: Regulation, Technology, and Markets, Michael Paetsch

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Mobile Data Communications Systems, Peter Wong, David Britland

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$$F_{dl}(n) = F_{ul}(n) + 95 \text{ MHz}$$

where

$$n = \text{ARFCN}, 512 \leq n \leq 885$$

5.3.5 PCS-1900/DCS-1800

Sometime during the first half of 1995, a PCS standard will start to take form in the United States. One of the proposed standards for North American PCS is the DCS-1800 system shifted up 100 MHz into the 1,900-MHz range, hence its name PCS-1900. Except for the difference in power level ranges and frequency bands ($F_{ul}(n) = 1850 \text{ MHz} + (0.2 \text{ MHz}) \cdot (n - 512)$ and $F_{dl}(n) = F_{ul}(n) + 80 \text{ MHz}$, $512 \leq n \leq 810$), this system is identical to the DCS-1800 standard. The frequency shift is required in the United States because of the presence of some point-to-point radio links on the 1,800-MHz band.

5.4 RADIO FREQUENCY POWER LEVELS

Radio equipment in GSM and DCS-1800/1900 are distinguished from each other by, among other things, the different transmitter power levels they can produce. The equipment is thus classified by the power classes shown in Tables 5.1 through 5.3. Each of the power levels in the various classes are separated from each other by something greater than 2 dB. For GSM, the minimum mobile station power level is 20 mW (13 dBm), and for DCS-1800 it is 2.5 mW (4 dBm). The relationship between dBm and watts is reviewed in Chapter 9, Section 9.2.1.

In the next-generation GSM, which is called Phase II or Phase 2, additional decreased power levels are introduced. There are also some new microcell applications

Table 5.1
Power Levels in the GSM System

Power Class	Maximum Power of a Mobile Station (dBm)	Maximum Power of a Base Station (dBm)
1	20W (43)	330W (55)
2	8W (39)	160W (52)
3	5W (37)	80W (49)
4	2W (33)	40W (46)
5	0.8W (29)	20W (43)
6		10W (40)
7		5W (37)
8		2.5W (34)

Table 5.2
Power Levels in the DCS-1800/1900 and Phase II System

Power Class	Max. Power of a DCS-1800 MS (dBm)	Max. Power of a DCS-1900 MS (dBm)	Max. Power of a DCS-1800 BTS (dBm)	Power of a DCS-1900 BTS (dBm)
1	1W (30)	1W (30)	20W (43)	20-40W (43-46)
2	0.25W (24)	0.25W (24)	10W (40)	10-20W (40-43)
3		2W (33)	5W (37)	5-10W (37-40)
4			2.5W (34)	2.5-5W (34-37)

Table 5.3
Power Levels for Micro-BTS in the GSM and DCS-1800/1900 Systems

Power Class	Max. Power of a GSM Micro-BTS (dBm)	Max. Power of a DCS-1800 Micro-BTS (dBm)	Power of a DCS-1900 Micro-BTS (dBm)
M1	0.25W (24)	1.6W (32)	0.5-1.6W (27-32)
M2	0.08W (19)	0.5W (27)	0.16-0.5W (22-27)
M3	0.03W (14)	0.16W (22)	0.05-0.16W (17-22)

that call for some micro-BTS power levels. The reduced BTS power levels are shown in Table 5.3.

5.5 TRANSMISSION ON THE RADIO CHANNELS

GSM allows radios to share its channel resources in both the frequency and time domains. The details of all the available frequency channels and bands were shown in Section 5.3. The methods used to make additional allocations in the time domain are called TDMA techniques, and these add considerable complexity to the system when compared to analog cellular systems. The reward, however, is better performance and additional features without squandering additional bandwidth for each user.

5.5.1 TDMA Frame

Considering that the GSM channel spacing is 200 kHz, it would be rather wasteful for a system not to subdivide this resource any further, since regulatory bodies and operators continue to strive for increased efficiency in the use of spectrum. To achieve this, the GSM system makes use of TDMA techniques with which each frequency channel is further subdivided into eight different time slots numbered from 0 to 7.

Each of the eight time slots is assigned to an individual user. A set of eight time slots is referred to as a **TDMA frame** (Figure 5.4), and all the users of a single frequency share a common frame. The frames will become more important in later discussions, as the complete system counts these frames and constantly refers to them. If a mobile, for example, is assigned time slot number 1, it transmits only in this time slot and stays idle for the remaining seven time slots with its transmitter off. The mobile's regular and periodic switching (on and off) of its transmitter is called **bursting**. The length of a time slot, which is equivalent to a **burst** from a mobile, is 577 μs , and the length of a TDMA frame is 4.615 ms ($8 \cdot 577 \mu\text{s} = 4.615 \text{ ms}$).

Compare the GSM spectrum allocation of 200 kHz per radio channel with the typical analog cellular system allocations of between 12.5 and 30 kHz. The use of TDMA techniques effectively reduces the allocation for each traffic channel to 200 kHz/8 = 25 kHz, which is equivalent to the typical analog system. This fact demonstrates that the GSM specification was selected for its additional quality and features rather than for increased capacity. The enhanced capacity TDMA affords, however, is an important feature of GSM, because to add the same GSM features and GSM quality to an analog system would require a significant increase in bandwidth for each user and render the "improved" analog system too inefficient to operate.

Although the TDMA structure gives the system more capacity, there is a price to pay. If a mobile station transmits a burst every 4.615 ms, then the underlying frequency is 216.6 Hz ($=1/4.615 \text{ ms}$), which is within the audible range. If, for example, a GSM mobile is operated close to a home stereo system, this frequency can be heard in the speakers. More serious is the impact on electronic devices such as hearing aids, cardiac pacemakers, or automobile electronics. Due to the relatively high power transmitted in the GSM mobile's bursts, they can have a significant

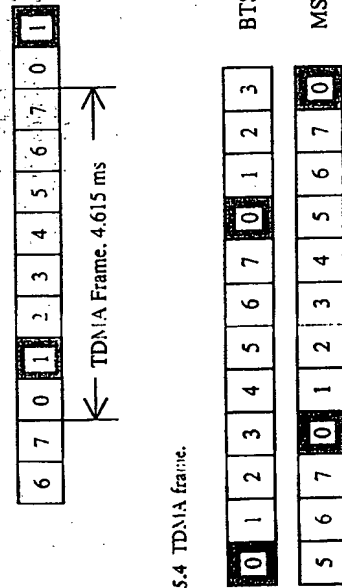


Figure 5.4 TDMA frame.

Figure 5.5 Time-division duplex in the GSM system.

influence. Some car manufacturers already suggest that a GSM mobile should only be used with an external antenna, because if used inside, the mobile phone may block or trigger the air bag or other important systems. Sorting out and clearing the risks and nuisances caused by GSM phones adds to the cost of designing and manufacturing them.

5.5.2 Time-Division Duplex

When using the TDMA technique, it is not necessary to transmit and receive signals at the same time in full-duplex mode. It is for this reason that TDD is introduced and used to great advantage in GSM (see Figure 5.5). The advantages for a mobile or a hand-held portable are numerous:

1. No need for a dedicated duplex stage (duplexer); the only requirements are to have a fast-switching synthesizer, RF filter paths, and fast antenna switches available;
2. Increased battery life or reduced battery weight;
3. Better quality (more rugged) and lower cost phones.

TDD tends to confuse those who have to repair digital phones. To make this feature less confusing for technicians and engineers and to increase some of the switching time specifications and lower costs, the GSM specifications stipulate that even though the time difference between transmit and receive functions is three time slots, the time slot numbering for both the BTS and the mobile station stays exactly the same. If both were using the same time slot at the same time. They are, of course, not doing so; the mobile station transmits three time slots later than the

5.6 PULSED TRANSMISSIONS

The requirement on the mobile station to transmit in only one single time slot and stay idle during the remaining seven time slots results in very tight demands on the switching in and out of the RF power. If a mobile station does not perform according to the specifications, it will disturb other mobile stations in adjacent time slots and in adjacent frequencies. The tendency for an unlicensed radio to disturb neighboring frequency channels is called **AM splatter**. The GSM specification makes sure a mobile's transmissions remain in its assigned channel by specifying a power-versus-time template.

An example of the power-versus-time template from the specifications is given in Figure 5.6. From this figure it can be seen that a mobile station has to switch on or off within only 2 μs and, during this short time, achieve a dynamic range of 40 dB. At the smaller power levels of 34 dBm and below, the dynamic range is a little bit more relaxed, since the absolute power level that must be achieved at

The GSM System for Mobile Communications

**A comprehensive overview of the
European Digital Cellular Systems**

The GSM System for Mobile Communications

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*This book would not exist if a group of European people had not taken a common aim and worked hard together to reach it.
This book is dedicated to all these mothers and fathers of GSM.*

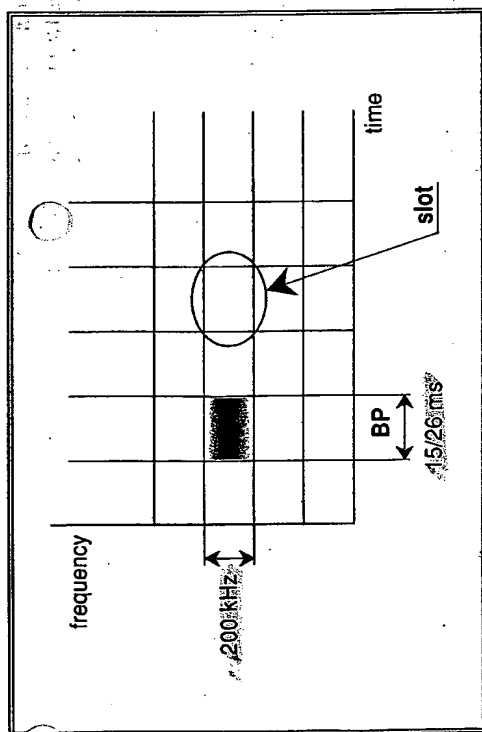


Figure 4.1 — A slot in the time and frequency domain

A transmission quantum in GSM (a burst) fits in a time and frequency window called a slot, which lasts about 577 μ s and occupies a bandwidth of 200 kHz.

A slot may therefore be pictured in a time/frequency diagram as a small rectangle 15/26 ms long and 200 kHz wide (see figure 4.1). Similarly, we will call a frequency slot (a radio frequency channel in the *Specifications*) a 200 kHz bandwidth as specified for GSM.

The above paragraph is heavy with terms and definitions. Once again, there is some difference between the choice of terms here and the one of the *Specifications*, because the terms such as timeslot or burst are used with several different meanings in the *Specifications*. For instance, burst refers sometimes to the unit time-frequency "rectangle", and sometimes to its contents. Likewise, timeslot is used to mean either what we call here "slot", or its time value, or also the cycle using one slot every eight slots in time.

To use a given channel means to transmit bursts at specific instants in time and at specific frequencies, that is to say in specific slots. To define a channel consists then to specify which slots can be used by, or are part of, the channel. Usually the slots of a channel are not contiguous

in time. A channel has therefore a temporal definition giving, for each time slot, the number of slots which are part of the channel. For the time being—and probably for quite a while...—a channel may only consist of 0 or 1 time/frequency slot per time slot. The temporal definition of a channel is cyclic, that is to say it repeats itself after some time. The simplest case of a cyclic definition is "1 burst every n". As will be seen on the next pages, the GSM channels are rarely as simple.

In parallel to the time definition, the frequency definition of a channel gives the frequency of every slot belonging to a channel. It consists basically of a function allocating a frequency to each time slot where a channel has a slot. There exists fixed frequency channels, for which the frequency is the same for every slot, and frequency hopping channels, whose slots may use different frequencies.

For bi-directional channels (e.g., a TCH), the two directions could have been defined in different ways. However, for simplicity reasons, the channel definitions for the two directions are always related in a very elementary manner: a fixed frequency gap (the "duplex separation") of 45 MHz (in the 900 MHz band) and of 75 MHz (in the 1.8 GHz band) and a time shift, which depends on the channel type, separate two corresponding slots of a given channel. In more academic terms, one direction is related to the other by a translation in time and in frequency.

4.2.1. THE TIME AXIS

The organisation of a channel along the time axis can be quite complex. This organisation is always cyclic, but the length of the cycle as well as the number of slots in a cycle vary according to the type of channel.

The positioning of the cycles in time is achieved through system synchronisation. Each cell provides a reference clock, defining the time slots, but also a "dating" scheme to which the cycles of all the channels are referred. In GSM, each time slot (and hence all the corresponding slots on the different frequencies) is given a number, which is known both by the base station and the mobile station, and which is part of the synchronisation information. The description of a given channel (e.g., sent by the base station to the mobile station) refers to this numbering scheme. The time slot numbering is cyclic, but of a very long cycle (3.5

Formally, a mobile station shall be considered in dedicated mode when a TCH is at its disposal. This corresponds to the phases when full bi-directional point-to-point transmission is possible between the mobile station and the infrastructure, for instance during a call established for the user, or to perform a location updating. TCHs and SACCHs are therefore referred to as dedicated channels in the *Specifications*.

When a mobile station is active (powered on) without being in dedicated mode, it is deemed to be in idle mode. However, the mobile station is far from being idle... It must continuously stay in contact with a base station, listen to what this base station transmits in order to intercept paging messages (to know if its user is being called) and monitor the radio environment in order to evaluate its quality and choose the most suitable base station. In addition, there is one telecommunications service which is provided to the mobile stations in idle mode: the Cell Broadcast Short Message service.

The transition between idle mode and dedicated mode requires some information exchanges between the mobile station and the base station (the "access" procedure). The mobile station indicates to the network that it needs a connection and the network indicates in return which dedicated channel it may use.

All of these uses require specific transmission means which are grouped under the terminology "common channels".

4.1.3.1. Access Support

In order to communicate with a base station, a mobile station must first become (and stay) synchronised with it. Two channels are broadcast by each base station to this avail: the FCCH (Frequency Correction Channel) and the SCH (Synchronisation Channel).

Mobile stations in idle mode require a fair amount of information to act efficiently. Most often, a mobile station can receive, and potentially be received by, several cells, possibly in different networks or even in different countries. It has then to choose one of them, and some information is required for the choice, for instance the network to which each cell belongs. This information, as well as much other, is broadcast regularly in each cell, to be listened to by all the mobile stations in idle mode. The channel for this purpose is the BCCH (Broadcast Control Channel).

Let us now come to the access. We have seen that paging messages have to be broadcast to indicate to some mobile stations that a call to its user is being set up. The access procedure itself includes a request from the mobile station and an answer from the base station, allocating a channel. Paging messages and messages indicating the allocated channel upon prime access are transmitted on the PAGCH (Paging and Access Grant Channel). This terminology combines the two terms "PCH" (Paging Channel) and "AGCH" (Access Grant Channel) used in the *Specifications*. Referring to two channels in that case is not consistent with the fact that the partition between PCH and AGCH varies in time, hence the concatenation in notation.

All the common channels listed above (FCCH, SCH, BCCH, PAGCH) are "downlink" unidirectional channels; i.e., they convey information from the network to the mobile stations. The last type of common channel, which allows the mobile stations to transmit their access requests to the network, is an "uplink" unidirectional channel. It is called the RACH (Random Access Channel). Its name indicates that mobile stations choose their emission time on this channel in a random manner. This results in potential collisions between the emission of several mobile stations, and will be studied in detail later.

4.1.3.2. The Cell Broadcast Short Messages

Cell Broadcast short messages require the means to transmit around one 80 octet message every two seconds from the network towards the mobile stations in idle mode. This corresponds to half the capacity of a downlink TCH/8. In each cell where this service is supported, a special channel, a CBCH (Cell Broadcast Channel) is used for broadcasting messages. A CBCH is derived from a TCH/8. Some special constraints exist for the design of this channel, because of the requirement that it can be listened to in parallel with the BCCH information and the paging messages.

4.1.3.3. A Point of Terminology: What is a Channel?

As noted a few times in the previous sections, we introduced some new terms in this book, and we will avoid some other terms though they are of common use in the *Specifications* and in the GSM literature. This

4.1.2. SIGNALLING

User data is not the only flow of information to be transported during a call. Signalling messages must also be conveyed; they allow the mobile station and the network to discuss the management of several issues either related to the user (e.g., call in progress indications) or concerning technical aspects of the communication (e.g., preparation and execution of handover). The establishment and release of a call also require signalling exchanges. In addition, we will see that some information exchanges between mobile stations and the infrastructure are needed even when no communication is in progress.

4.1.2.1. Signalling in Connection with a Call

In order to transport signalling data in parallel with the transmission of a user data flow, GSM offers two possibilities. Each traffic channel comes with an associated low rate channel, used for the transport of signalling: the SACCH (Slow Associated Control Channel). This bi-directional channel may carry about 2 messages per second in each direction, with a transmission delay of about half a second. It is used for non-urgent procedures, mainly the transmission of the radio measurement data needed for the decisions concerning handover.

The other needs for associated signalling, such as the messages to indicate the call establishment progress, or to authenticate the subscriber, or to command a handover, to give only a few examples, make use of the TCH itself. This usage shall be referred to here as fast associated signalling, in place of the term FACCH (Fast Associated Control Channel) used in the *Specifications*. Fast associated signalling does not indeed refer to a channel in our use of the term, but to a particular use of a TCH.

The receiver is able to distinguish both uses by reading a binary information transmitted on the TCH and called the stealing flag (see page 237). During the initialisation and release phases, no user data is transmitted and therefore signalling may use the channel without any conflict with other types of data. However, during the call, the transmission of fast associated signalling is done to the prejudice of user data: there is a loss of user data as all transmission errors (of known location) had occurred. Hence the term "stealing".

FACCH
- current's on rd?
- handover - comments
- publication per 100 km² min²

stealing flag!

4.1.2.2. Signalling outside a Call

In some cases, there is a need to establish a connection between a mobile station and the network solely for signalling matters, be it at the user's demand (e.g., call forwarding management, transmission of short messages) or for other management needs, such as location updating.

A TCH/F or a TCH/H may be used for that purpose. This is however wasting a lot of spectrum, since few messages are to be exchanged (typically half a dozen each way) and the channel would only be used for a very small portion of the time.

In order to increase system efficiency, an additional type of channel has been introduced. Its rate is very low and the only specified usage—so far—for this channel is signalling (and short messages transmission). This channel shall be referred to here as TCH/8 where "8" stands for "eighth". If a TCH/H may be considered as half a TCH/F, then this small channel is one eighth of a TCH/F. This terminology diverges from the GSM one, where this channel is called SDCCH (Stand-alone Dedicated Control Channel, not a very enlightening term). The characteristics of such a channel are in fact very close to those of a TCH/F or H, the prevalent difference being its rate. The choice of vocabulary in the *Specifications* stems from the fact that no user data mode has been specified for the TCH/8. However, this does not appear the most pertinent distinction, given the definition of a channel (see page 193)! Moreover, nothing would fundamentally preclude an evolution of the *Specifications* to use a TCH/8 as a traffic channel, for instance for low rate data services like telemetry. A pragmatic reason for this change of terminology is to avoid in many places "TCH or SDCCH".

As the other TCHs, a TCH/8 is bound to an SACCH. The notion of fast associated signalling also applies to a TCH/8, but for the moment it is a trivial matter, since it is the only usage of a TCH/8.

SDCCH 10 min² per 100 km²
- 10 min² per 100 km²

4.1.3. IDLE MODE

The rarity of the radio spectrum does not allow each user of the system to have his own TCH at all times. Traffic channels are therefore allocated to the users only when the need arises. This leads us to the basic distinction of dedicated mode and idle mode, which is an essential concept in radiotelephony.

hours), which has been chosen as a multiple of all cycles needed for multiple access. Within each period, any slot can be unambiguously referred to by its time slot number and its frequency slot number.

4.2.1.1. Dedicated Channels

TCH/F and its SACCH

SACCH
A TCH/F is always allocated together with its associated slow-rate channel (SACCH). The resulting group of channels bears unfortunately no specific name in the *Specifications*, and is therefore often confused with the TCH/F part only. Because we found the distinction useful, and to avoid long paraphrases, we choose to introduce a non GSM term. The group TCH/F plus SACCH shall be referred to in this book as a **TACH/F**.

A TACH/F has a simple cyclic definition. It consists of one slot every 8 BP in each direction, i.e., one slot every 4.615 ms (or, better, 50/13 ms). A consequence of this definition is that it consists in the slots whose time slot number is 8 times an integer plus a value k between 0 and 7 specific to the channel. This value k is the phase modulo 8 of the numbers of the slots of the channel. It is called in the *Specifications* the *Time slot Number (TN)* of the channel. Let us point out that this meaning of *Time slot Number* is not the same as a few lines above, but TN is the GSM term and is the abbreviation of *Time slot Number*. In the following, we will use TN only in short form, to limit the confusion.

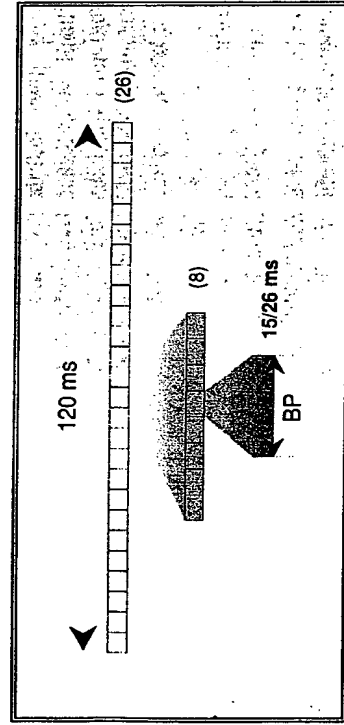


Figure 4.2 – Choice of value of a burst period
The exact value of a burst period is derived from a multiple of 20 ms by applying two multiplexing schemes ($\times 26 \times 8$).

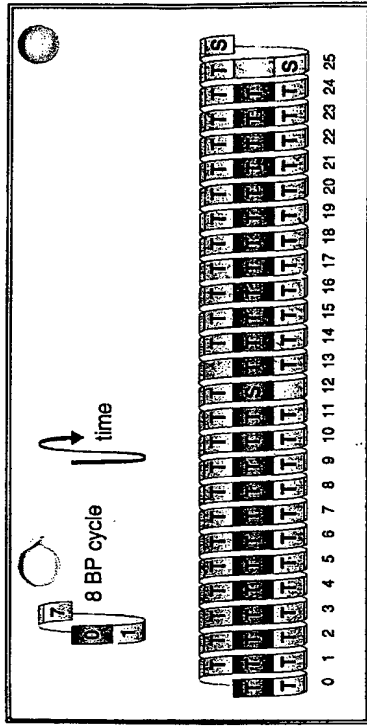


Figure 4.3 – Time organisation of a TACH/F

A full rate TACH uses a cycle of 26×8 slots. Within each of these cycles, 26 slots are used for the TCH/F and one slot for the corresponding SACCH.

In order to spread the arrival of SACCH messages at the base station, the cycles of two TACHs using successive slots are separated by 97 BPs (i.e., 12×8 , plus the difference of one slot).

Eight different types of TACH/F can therefore be defined depending on their phase modulo 8 (their TN). Two TACH/F with the same phase consist of simultaneous slots.

On the network side, 8 TACH/F with different TNs may be emitted by a single transmitter at any given moment, a single TACH/F of the group is to be emitted. This is the core of the concept of TDM (Time Division Multiplex). This is an important aspect of the system, leading to substantial savings in the base station.

A TACH/F contains a TCH/F and an SACCH. The split between these two channels is also specified in the time domain, using a cycle of 26 TACH/F slots, i.e., 26×8 successive slots, or a period of 120 ms. The value 120 ms is an exact one; which was chosen as a multiple of 20 ms in order to obtain some synchronism with fixed networks, ISDN in particular. We then can explain the reason of the strange value of BP: the BP is therefore exactly $120/26 \times 8$ ms, i.e., 15/26 ms (see figure 4.2).

The TACH/F 26 slot cycle includes 24 slots on which TCH/F bursts are sent, 1 slot on which an SACCH burst is sent, and one slot where no transmission takes place (see figure 4.3).

Coding follows cycles based on the grouping of 4 successive bursts, as will be explained on page 247. For the TCH/F, a cycle contains 6 times 4 bursts. However, for the SACCH, the full cycle, taking into account this grouping 4 by 4, lasts $4 \times 26 \times 8 = 104 \times 8$ BPs, i.e., 480 ms.

4.2.1.2. Common Channels

General Organisation

All common channels have been defined with the intention of grouping them together in few combinations. Their time definitions are therefore all based on the same cycle, i.e., 51×8 BPs.

This cycle and the cycle of traffic channels were deliberately chosen with different values (in fact, they were chosen not to have any common divider) in order to allow mobile stations in dedicated mode to listen to the synchronisation channel (SCH) and frequency correction channel (FCCH) of surrounding base stations, both of which carry the information needed for mobile stations to become and stay synchronised with a cell. With the numerical relationship between the cycle of the common channels and the cycle of the TACH/F or H, the bursts of the common channels file off one after the other in front of the reception windows of the mobile stations situated in surrounding cells, and in particular in front of the large window left open in a TACH/F cycle by the unused slot. These mobile stations are then able to receive—at least from time to time—a burst belonging to the FCCH or to the SCH. By so doing, they acquire the synchronisation information they need on surrounding cells, whatever the relation between time bases of neighbouring base stations (which may be anything indeed). This functionality is referred to as “pre-synchronisation” and is part of handover preparation: the reader will find more on that topic in Chapter 6.

FCCH and SCH

Both the FCCH and the SCH have the same time structure: one

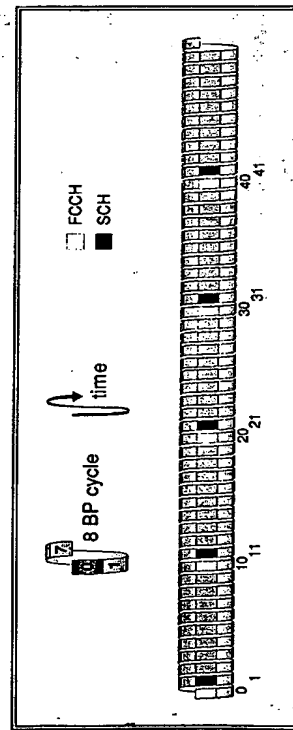


Figure 4.8 – time organisation of the FCCH and SCH

Once a mobile station has found an FCCH burst, it knows that the SCH slot can be found 8 BPs later on the same frequency.

SCH slot follows each FCCH slot 8 BPs later. Each of those two channels uses 5 slots in each 51×8 BPs cycle, as shown in figure 4.8.

A single set (FCCH + SCH) is broadcast in any given cell. In all cells, the slots of these channels have the same position within the 8 BP cycle, that is to say the same TN. This position is by definition called TN0. Indeed no burst on the radio interface carries its TN, and the mobile station knows the TN of a slot only by reference to the FCCH and SCH. Every burst of the SCH indicates the remaining part of the time slot numbering (i.e., the remainder modulo 8), thereby enabling mobile stations to derive the numbering of all slots within the cell.

BCCH and PAGCH

Apart from the SCH and FCCH, the other downlink common channels include the BCCH and the PAGCH, introduced on pages 192 and 193. The difference between these two channels lies more in their usage than in their transmission characteristics. It is indeed possible that, in later phases of the system, their respective size may be allowed to vary, e.g., in order for the BCCH to gain some capacity at the expense of the PAGCH capacity.

Two kinds of PAGCH are defined, which have different capacities, hence which use a different number of slots per cycle. They do not bear a specific name in the Specifications; they will be called here PAGCH/F (“full”) for the larger one and PAGCH/T (“third”) for the smaller one, by analogy with the dedicated channels terminology.

A BCCH together with a PAGCH/F uses 40 slots per 51×8 BP cycle, all with the same TN. Figure 4.9 shows how these slots are spread. These 40 slots are built as 10 groups of 4, the four slots of one group

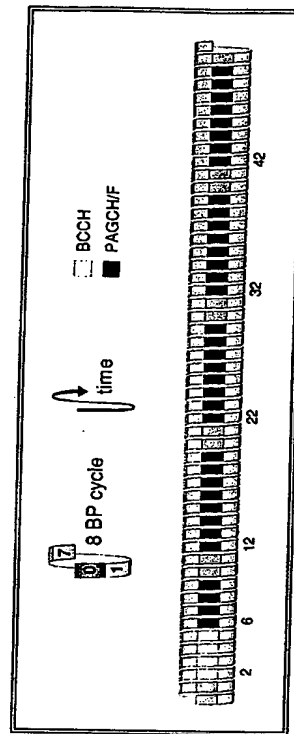


Figure 4.9 – Time organisation of a BCCH and a PAGCH/F

The BCCH uses 4 slots per 51×8 BP cycle, and 36 slots are dedicated to the Paging and Access Grant channel.

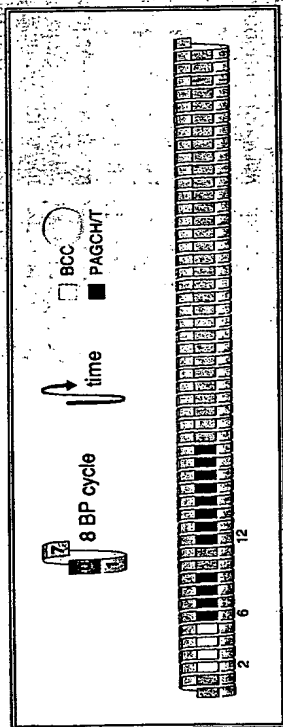


Figure 4.10 – Time organisation of a BCCH and a PAGCH/T

A PAGCH/T uses 12 slots per 51×8 BP cycle, i.e., one third of a PAGCH/F.

being separated by 8 BPs and containing bursts from a single coding block. The BCCH uses the first quartet and the PAGCH uses the 9 other quartets.

A BCCH together with a PAGCH/T uses 16 slots per 51×8 BP cycle, all with the same TN. Figure 4.10 shows how these slots are spread. These 16 slots are organised as 4 groups of 4. The BCCH uses the first quartet and the PAGCH uses the 3 other quartets (hence one third of the PAGCH/F).

RACH

As for the PAGCH, two types of RACH exist: the RACH/F and the RACH/H. The RACH/F uses one slot every 8 BPs, so that its time organisation is similar to the one of a TACH/F in the uplink direction.

On the other hand, a RACH/H only uses 23 slots in the 51×8 cycle, and its capacity is therefore slightly more than half the one of a RACH/F. The time organisation of a RACH/H is shown in figure 4.11 and allows the combination of a RACH/H with 4 TACH/8s.

Common Channels Combinations

Every cell broadcasts one single FCCH and one single SCH. As far as the BCCH, PAGCH and RACH are concerned, every cell supporting mobile access must have at least one of each (one may however imagine cells accessible only through handovers, in which case these channels would not be necessary).

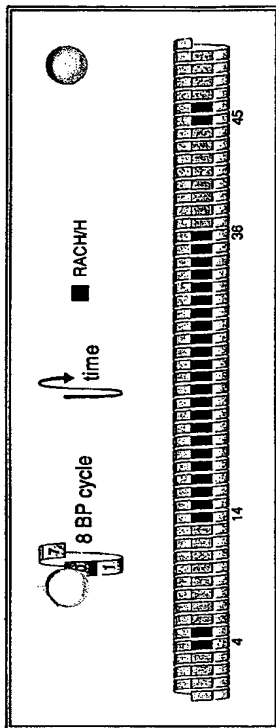


Figure 4.11 – Time organisation of a RACH/H

A RACH/H fits in the bursts left free in the uplink by 4 TACH/8s, i.e., it uses 27 bursts during each 51×8 BP cycle.

In order to save spectrum, common channels are always arranged in groups; there are 3 such possible combinations.

The basic combination includes (in the downlink direction) a FCCH, a SCH, a BCCH and a PAGCH/F, all of the same TN, namely 0. The uplink direction contains a RACH/F. This arrangement is shown in figure 4.12. All these channels together use the same amount of resources as a TACH/F, which allows a single base station transmitter to manage such a combination plus 7 TACH/Fs (of TNs 1 to 7).

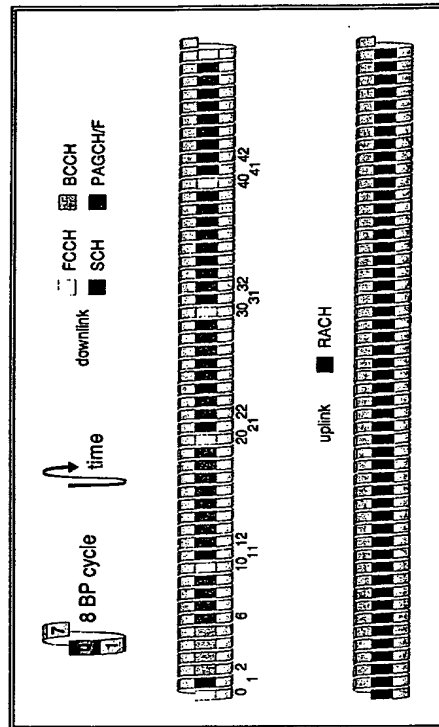


Figure 4.12 – Basic common channel pattern

A typical medium cell common channel pattern uses TN 0 of one carrier for FCCH, SCH, BCCH, PAGCH/F and RACH/F.

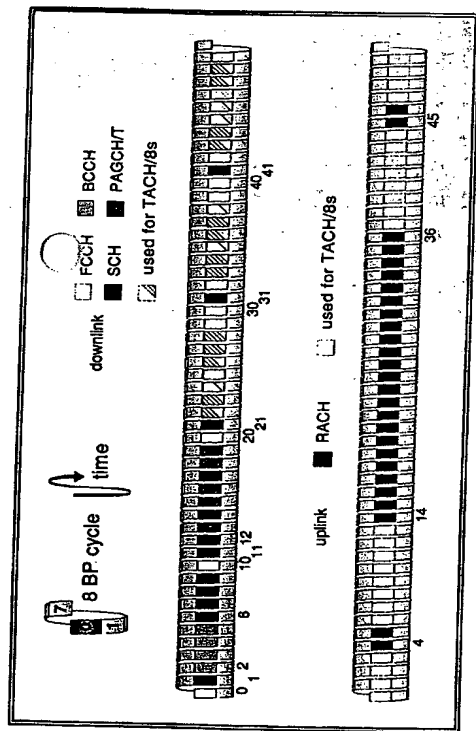


Figure 4.13 - A common channel pattern for small capacity cells

A typical common channel implementation of a small capacity cell combines 4 dedicated channels (TACH/8s) used for signalling with a set of common channels (FCCH, SCH, BCCH, PAGCH/T and RACH/H)

The second combination has been introduced with the small capacity cells in mind (which are usually not the smallest in geographical size...). When the capacity of a PAGCH/T and a RACH/F are not needed, the operator might be interested in combining:

- in the downlink direction, a PAGCH/T with the usual FCCH, SCH, BCCH plus 4 downlink TACH/8s;
- in the uplink direction, a RACH/H with 4 uplink TACH/8s.

Such a combination is shown in figure 4.13. As for the basic combination, this one uses TN 0.

Conversely, the third combination is used in very high capacity cells, in which a PAGCH/F and a RACH/F are not sufficient to cope with too high a traffic level. On top of a set of channels grouped as in the basic combination (i.e., with PAGCH/F and RACH/F), a cell may accommodate up to 3 extension sets, each set following the third combination. An extension set contains the same channels as the basic combination, except the FCCH and SCH (they must be unique in the cell). A BCCH appears in each extension set, at least for two reasons: first, a part of the information broadcast on the BCCH relates to the RACH of the same TN, and hence can differ from one TN to another; second, it is simpler for the mobile station to listen to bursts of a single TN only.

These extension sets are found on TN 2 (one extension), TNs 2 and 4 (two extensions), or TNs 2, 4 and 6 (three extensions). Why impose this constraint? The reasons are the following:

- first, all common channels of one cell must use the same downlink frequency (and therefore the same uplink frequency): this will be explained when exploring the frequency realm page 224;
- second, cells of very large radius may allow RACH bursts to overflow into the next slot, as explained in Chapter 6. If consecutive TNs had been allowed for extension sets, they would not be compatible with such possibilities;
- third and last, it was desirable to simplify the system complexity by minimising the number of different cases.

CBCH

A Cell Broadcast Channel (CBCH) follows a cycle of $8 \times 51 \times 8$ BP (lasting for about 2 seconds), where 4 times 4 slots are used. The allowed positions in the 51×8 BPs cycle, and the allowed TNs, are limited, so that there is no collision with the requirement to listen to other BCCH or PAGCH information. The CBCH can be seen as a sub-part of a TCH/8. Two cases are to be distinguished. If the common channel configuration is the small one with a PAGCH/T and a RACH/H, the CBCH can use the same TN (TN 0) and frequency as the common channels. It then uses slots that would otherwise belong to one of the four TCH/8s which can use TN 0 and the beacon frequency. A second possibility, applicable whatever the common channels configuration, is for the CBCH to use TN 0 (but not on the beacon frequency), 1, 2 or 3; the CBCH bursts must then again use a specific position in the 51×8 BP cycle, which would otherwise belong to a TCH/8.

When a CBCH is used, the first block of the PAGCH in the 51×8 cycle cannot be used for paging. All these rules ensure a minimum time between a CBCH burst and a burst belonging to a block carrying a paging message. However, in this second case, it is allowed (but not mandatory) to have a CBCH with a TN different than 0. In this case, the mobile station in idle mode has to listen regularly to bursts of different TNs, a source of complexity for the scheduling of reception. This is the sole case where such a requirement exists within one cell.

TCH/H

The half-rate TCH, or TCH/H, has led an eventful life. Until the beginning of 1991, a TCH/H was fully specified for data services, but not yet for speech. The following description will refer to that specification. However, as explained in the previous chapter, "half-rate" speech coding studies (i.e., studies aiming at defining a speech coding scheme adapted to transmission on TCH/Hs), which were under way in early 1991, have shown that the time structure chosen for TCH/Hs was not necessarily optimum. It was therefore decided that the half-rate TCH was no longer part of the phase 1 Specifications, even for data services.

As for a TCH/F, a TCH/H is always allocated together with its SACCH, and this group of channels will be referred to as TACH/H. A TACH/H is defined in the time domain as consisting on average of one slot every 16 BPs, hence the "half-rate" compared to a TACH/F. The term "on average" is important here, because it is not true that all the TACH/Hs are defined as exactly each sixteenth slot, as the TACH/F is defined as exactly each eighth slot. It is true for half of the TACH/Hs, but not for the other, for whom the cycle is 13×16 BP long. The cycle is shown in figure 4.5. It should be noted however that in both cases, a TACH/H consists only of slots of the same TN. This state of affairs is unfortunate for the simplicity of the description, and for the mobile station implementation (the two categories of TACH/H differ by more than a translation). It has no clear reason, and will quite likely be modified before half rate channel specifications are completed.

As far as the time definition is concerned, there are 16 kinds of TACH/H, which are usually referenced by their TN (8 values) plus a sub channel number (sub-TN, 0 or 1). For a TACH/H of sub-TN 0, the time slots of the TCH/H are of even number modulo 16,

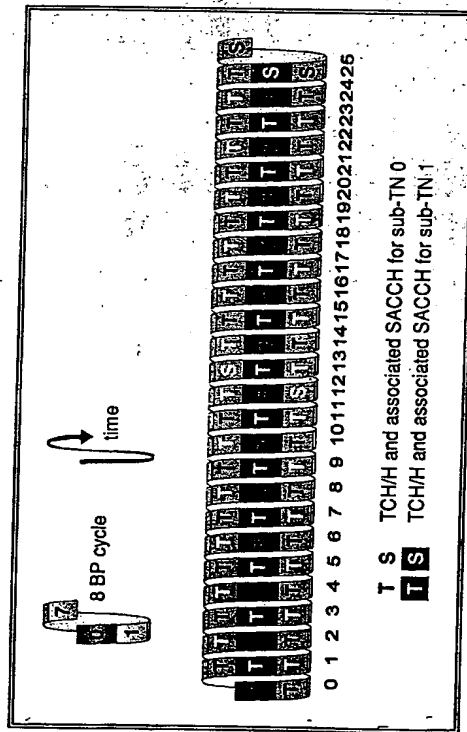


Figure 4.5 – Time organisation of TACH/Hs

A TACH/H, as defined provisionally, uses one slot every 16 in average.

On "even" TNs, they use exactly one slot every 16.

On "odd" TNs, the scheduling is not so regular,

as can be seen on TN 1 or 7 (occurrences 11, 12, 13 for the channel of sub-TN 1, and for occurrences 24, 25, 0 for the channel of sub-TN 0).

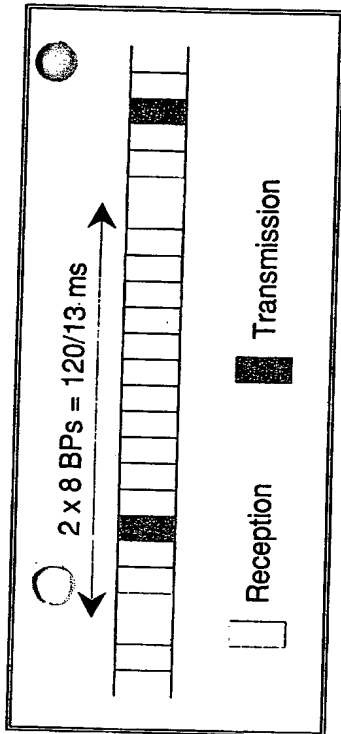


Figure 4.6 – Cycle of 16 BPs seen by a mobile station

A mobile station using a TACH/H performs the same operations as for a TACH/F (same timing between reception and emission), but does so only every other group of 8 bursts.

whereas they are of odd number in the case of sub-TN 1. Now TACH/H of TN 0, 2, 4, 6 are well-behaved, in the sense they use exactly each sixteenth slot, whereas the others have the irregular cycle.

The crafting of the TACH/H was done so that the two TACH/H of the same TN but of different sub-TN have no simultaneous slot, and then may be grouped to form the equivalent of a TACH/F. Such TACH/H pairs and/or TACH/Fs may then be grouped in 8s for a single transmitter in a base station. A transmitter may accommodate up to 16 TACH/Hs, or more generally a combination of 8 sets, each set containing either a TACH/F or a pair of TACH/Hs.

The split between a TCH/H and its SACCH is done for the well behaving TACH/H along a cycle of 13 TACH/H slots, i.e., 120 ms as for the TACH/F. The cycle contains 12 slots for the TCH/H bursts and one for the SACCH. All the slots of the TACH/H are then used for transmission. For the other category of TACH/H, the cycle is less regular, as shown in figure 4.5 for TNs 1 or 7.

As for the full-rate channel, a complete cycle lasts 480 ms (104×8 BPs) when coding is taken into account, and the start of cycles is defined in the same way. The reader may have noticed that the SACCHs have the same time organisation as those associated with TCH/Fs. Half of them (those with sub-TN 0) are emitted exactly as if they were associated with a TCH/F of the same TN, the other half (those with sub-TN 1) being emitted during the slot which would be free in the cycle of a TCH/F of the same TN.

The timing offsets between TACH/Hs of different TNs is similar to the one defined for TACH/Fs: a TACH/H of TN $n+1$ is shifted 97 BPs compared to the TACH/H of TN n and of different sub-TN, so that it is shifted twice 97 BPs compared to a TACH/H using TN n and the same sub-TN. The uplink and downlink directions are also related in the same manner as those of full-rate channels: an uplink slot follows a downlink slot 3 BPs later (at the base station). As seen by the mobile station, the 16 BP-cycle of a well-behaved TACH/H can be pictured as shown in figure 4.6.

TCH/8

The description of a TACH/8 (i.e., a TCH/8 and its SACCH) is somewhat more complex than the one of the full, and even of the half rate TACHs, because there exists many different kinds of TACH/8s from the point of view of the time organisation:

- some may be grouped by 8 to form the equivalent of a TACH/F: they are called SDCCH/8 in the GSM terminology;
- others may be grouped by 4 and combined with common channels to form all together the equivalent of a TACH/F: they are called SDCCH/4 in the GSM terminology.

All TACH/8 have many properties in common: they all follow a cycle of 102×8 BPs, where 8 slots are used for the TCH/8 bursts (a group of 4 slots separated by 8 BPs, then 51×8 BPs, then again a group of 4 slots separated by 8 BPs, ...) and 4 slots are used for the SACCH bursts (one group of 4 slots separated by 8 BPs). The attentive reader will have noticed that the length of the TACH/8 cycle (102) bears no simple relationship with the TACH/F cycle (26, and 4 times 26, is 104). The origin of this choice lies in the possibility to associate 4 TACH/8s with common channels; the latter follow a 51×8 BPs cycle, as will be explained in a few paragraphs. In order to keep some homogeneity between the different TACH/8s, this cycle has been used also for the TACH/8s crafted to be grouped by 8, though a cycle of 52×8 could have as easily been chosen. This difference between the length of the TACH/8 cycle and the one of the TACH/F or /H results in slightly different rates (2% difference) for the corresponding SACCHs.

The TACH/8 vary in their phase relations between the TCH slots and the SACCH ones, as well as between the uplink and downlink directions. Figure 4.7 shows the time organisation for both categories of TACH/8.

From the figures it is obvious that the TACH/8 cannot be derived one from each other by a simple translation in time. The result is that there are 12 different schedulings for mobile stations in connection on a TACH/8. In fact the figure shows 4 cases (2 in the case of grouping by 8, and 2 in the case of grouping by 4), but the notion of measurement reporting period (dealt with in Chapter 6) results in 12 classes (the same notion does not have similar impacts on the TACH/F and the TACH/H).

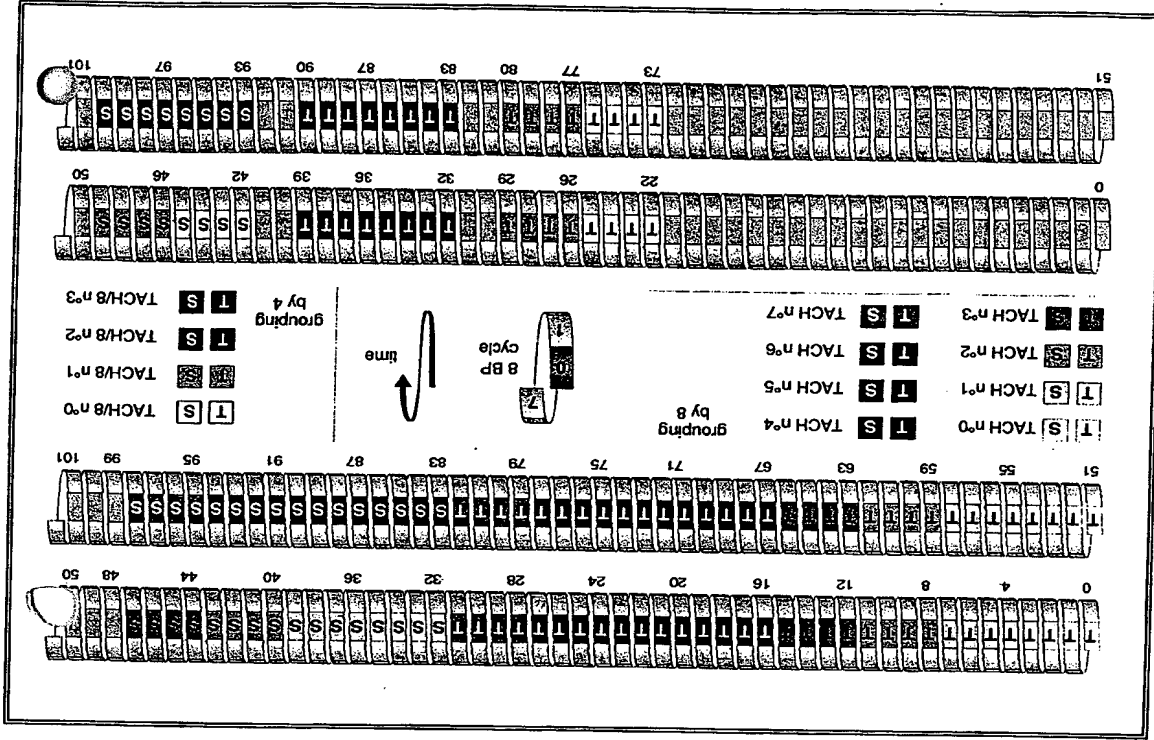


Figure 4.7 - Time organisation of TACH/8s

TACH/8s can be grouped by 4 or by 8 in a cycle of 102×8 BPs. During this cycle, 2 blocks of 4 slots are used for a TCH/8 and 1 block of 4 slots for its SACCH.

The uplink cycles can be obtained by a simple translation of 66×8 BPs.

The position in time of the full 104×8 cycle of a TACH/F is the same for all the TACH/Fs of the same TN in a given cell. We will try to describe the relationship between the different TN in simple terms. The position in time of the TCH/F bursts (by opposition to the SACCH and unused slots) follows a 13×8 BP cycle. The beginnings of this cycle are almost simultaneous for the TCH/F of different TNs, in the sense that the first slot of the 13×8 cycle of a TCH/F of TN 1 follows immediately the corresponding slot for a TCH/F of TN 0. Very exactly, they follow each other from 0 to 7. But the start of the SACCH cycle for the different TNs do not happen in the same 8 BP interval. Still, all the TACH/F have the same definition in the time domain, except for a translation in time. This translation invariance property is important for the design of a mobile station: it means that the scheduling of the treatment for all TACH/F is the same, the only impact of the TN is that the scheduling starts at different moments.

The reason for the shifting of the 104×8 BP cycles comes from load considerations in the infrastructure. If the SACCH had been almost simultaneous, the base station would have received the SACCH messages from all the mobile stations almost simultaneously every 480 ms, resulting in a very uneven load. In order to avoid that drawback, the cycle of a TACH/F using TN $n+1$ (for n from 1 to 7) is shifted $(12 \times 8) + 1 = 97$ BPs from the one of a TACH/F using TN n . This shift can be seen in figure 4.3; since four bursts are necessary to build an SACCH message, the base station will process the SACCH messages corresponding to 8 TACH/F of TN 0..7 at 8 different moments evenly spread in time.

Relationship between Uplink and Downlink

As seen from the base station point of view, the organisation in the uplink direction is derived from the downlink one by a delay of 3 BPs. This delay of 3 BPs is a constant throughout GSM. In fact, the convention is that the numbering of the uplink slots is derived from that of the downlink ones by a shift of 3 BPs; this choice allows the slots of one channel to bear the same TN in both directions.

But the point of view of the mobile station is affected by considerations about propagation delays which, even at the speed of light, are not negligible compared to the burst duration (the round-trip delay between an MS and a BTS 30 km apart is 200 μ s). In a first step, we will ignore the problems due to propagation delays, and consider that a mobile station very close to the BTS sees the 8 BP cycle as shown in figure 4.4.

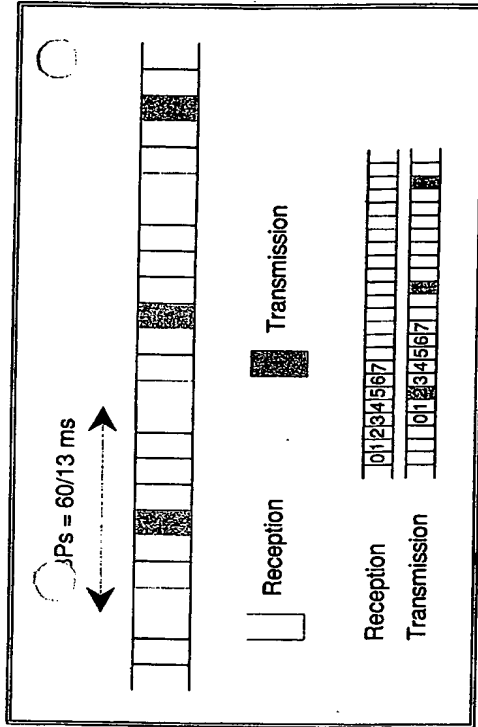


Figure 4.4 – Cycle of 8 BPs seen by a mobile station close to the base

Emission by a mobile station happens 3 BPs later than Reception. Typically, a mobile station will receive during one time slot, then shift in frequency by 45 MHz to emit some time later.

(3 burst periods minus the correction in time for propagation), then possibly shift again to monitor other channels, and move to the adequate receive frequency to start the cycle all over again.

Such a choice allows mobile stations to avoid emitting and receiving simultaneously, thereby promoting easier implementations: the receiver in the mobile station need not be protected from the emitter of the same mobile station.

When the mobile station is far from the BTS, propagation delays cannot be neglected and an exact 3 BP shift cannot be maintained both at the MS and at the BTS. But it is imperative that the bursts received at the BTS fit correctly into the time slots, and as we will see this is not very roomy. Otherwise, the bursts from mobile stations using adjacent time slots could overlap, resulting in a poor transmission quality or even in a loss of communication. The only solution is that the mobile station advances its emission relatively to its reception by a time compensating the to and fro propagation delay. This value is called the timing advance. The exact shift between downlink and uplink as seen by the mobile station is then 3 BP minus the timing advance. The timing advance value can be computed only by the BTS and is then provided to the mobile station through signaling. This is why we have chosen to deal completely with this subject in Chapter 6.

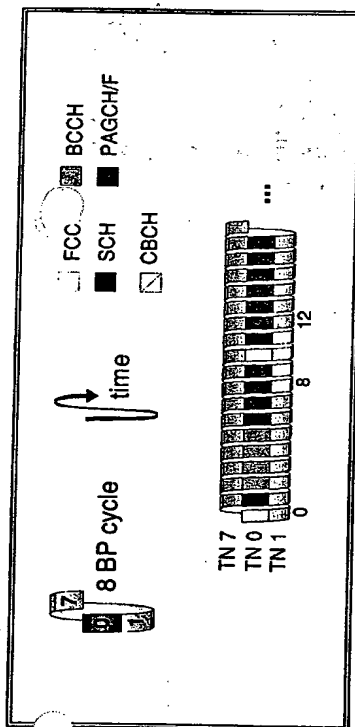


Figure 4.14 - Time organisation of a Cell Broadcast Channel (CBCH)

A CBCH uses part of the capacity which would otherwise be allocated to a TACH/8. The example shows the CBCH when combined with TACH/8s on TN 1.

Inside the $8 \times 51 \times 8$ BP cycle, the CBCH can be seen as a half downlink TCH/8, using four out of the eight 4-burst blocks. The example of a CBCH using TN 1 is given in figure 4.14. The four other blocks, i.e., the slots that would be used by the SACCH, and the uplink corresponding slots, are not used by the CBCH, and cannot be used for anything else. However, it is allowed to stop the transmission of the CBCH in case of congestion, and then these resources can be used for a TACH/8 during such periods.

4.2.1.3. Channel Organisation in a Cell

The above sections have mainly taken into account the mobile station point of view when describing the channels. A few ideas of how channels may be grouped in a cell have been introduced; let us now dig deeper into the management of time resources by a base station.

An elementary transceiver can emit or receive continuously, but on a single frequency slot at any given instant: it may be able to change its frequency as often as once every burst period, but it cannot emit or receive two bursts on different frequency slots during the same time slot. A base station usually contains several such elementary transceivers in order, to reach the desired capacity. This concept of elementary transceiver is used in the *Specifications* (mainly in the specification of the interface between BTS and BSC) under the term *TRX* (Transmitter Receiver).

Channels	Unused slots
1 TACH/F	1 out of 26
2 TACH/H of different sub-TNs	none
8 TACH/8 of different sub-TNs	3 out of 51
1 SCH + 1 FCCH + 1 BCCH + 1 PAGCH/F + 1 RACH/F	downlink: 1 out of 51 uplink: none
1 BCCH + 1 PAGCH/F + 1 RACH/F	downlink: 11 out of 51 uplink: none
1 BCCH + 1 PAGCH/T + 1 RACH/H + 4 TACH/8	downlink: 3 out of 51 uplink: none

Table 4.1 - Possible combinations of channels of the same TN

The same capacity of one slot every 8 slots may be used for various combinations, some examples of which are given in this table.

It is therefore desirable, in order to optimise implementation costs in a base station, to choose channels so that they form groups where at most one burst is emitted at any one time, and to fill the time slots within these groups as much as possible.

In order to facilitate such groupings, the time organisation of the radio interface makes an extensive use of the 8 BP cycle. Every TRX is able to cope with 8 groups of channels, each group corresponding to a given TN. For instance, a group of channels using the same TN may consist of one of the combinations listed in table 4.1 (the CBCH is not included).

A TRX may combine eight such groups, with only the constraints listed earlier on common channels, in particular the TN(s) to use. The three combinations using only TACHs may exist on any TN. In order to complete the picture, let us give a few examples of channel combinations in a cell.

A small capacity cell with a single TRX will typically be organised as follows:

TN 0: FCCH, SCH, BCCH, PAGCH/T, RACH/H, 4 TACH/8;
TN 1 to 7: 1 TACH/F each.

A medium capacity cell with 4 TRXs may include:
 one TN 0 group: FCCH, SCH, BCCH, PAGCH, TACH/F;
 twice 8 TACH/8; and
 29 TACH/F.

A large capacity cell with 12 TRXs may include:

one TN 0 group: FCCH, SCH, BCCH, PAGCH/F, RACH/F;
 one TN 2 group, one TN 4 group and one TN 6 group: BCCH,
 PAGCH/F, RACH/F;
 5 times 8 TACH/8; and
 87 TACH/F.

4.2.1.4. Synchronisation Acquisition, or "How did it all start?"

Any reader who is not an expert in synchronisation might well at this stage ask the reasonable question: how does the mobile station manage to find the very first synchronisation with a cell, in order to read any of the channels defined in the previous paragraphs? What kind of bootstrap is there?

A few explanations might clarify the issue. As already mentioned, the FCCH and the SCH are provided for helping the mobile station to acquire the synchronisation. More precisely, the successful reception of an SCH burst will give the mobile station all the information needed for synchronisation. The problem is then to find an SCH burst. The specifications are such that an SCH burst always follows an FCCH burst 8 BPs later on the same frequency. Now an FCCH burst has a rather easily recognisable structure. A possibility is then to look for FCCH bursts, at all frequency slots and at all times.

When such a burst is encountered, the mobile station is able to get some information out of it. First (as the name FCCH evokes), it is able to correct the frequency of its internal time base in order to ease the demodulation of other channel bursts—this is however not the main point here. What is more important for synchronisation acquisition is that the mobile station is able to have a rough idea of the boundaries between slots, and of the situation in time of the slots of TN 0 (since the FCCH uses by definition slots of TN 0).

Knowing how SCH slots are positioned relatively to FCCH slots, the mobile station may then proceed to find and demodulate an SCH

burst. Inside, it will find some precise information on the limits between slots, as well as sufficient information to deduce the number of the time slot in the cycle of $8 \times 26 \times 51 \times 2048$ BPs, and hence its position in all useful cycles. From this moment onwards, the mobile station only needs to maintain its knowledge of slot boundaries and to add 1 at each BP!

4.2.1.5. Frames

This small section is not aimed at adding more explanations on the time organisation of the channels. The previous sections were to give all explanations, and it is hoped they have reached their goal. Yet, the proposed description is quite different than what can be found in the *Specifications*, or in the main literature on GSM (which usually follows the same approach as the TSs). In the following paragraph we will try to bridge the gap.

In the *Specifications*, the time description of channels refer to "frames", a word which we did not use in this context. A frame is often presented as the succession of n slots. In particular, a "TDMA frame" represents a succession of 8 consecutive slots, the accent being put on the grouping of slots rather than on the 8 BP cycle. The grouping vision is quite natural when dealing with the implementation of a base station, which caters for many channels. But the cycle approach is much more natural as seen from the mobile station, which deals with few channels at the same time. This is why we preferred to put the stress on the concept of cycle (shown as an helix in the figures) rather than use the notion of "frame".

However, since the numbering of slots in GSM is very much based on frames, it is worth presenting the GSM frame hierarchy now. In the *Specifications*, a TDMA frame most often refers to a grouping of 8 time slots starting with one of TN 0. This allows to use the "TDMA frame number", which is simply the quotient modulo 8 of the time slot numbers of the time slots in the frame. But because all the channels are designed as having only slots of the same TN, the full time slot numbering is never used in the *Specifications*. Instead, one finds the TDMA frame number (FN) plus the TN.

There are other frames appearing in the *Specifications*, corresponding to the major cycles. They are shown in figure 4.15.

The "26 TDMA frame multiframe" is defined as a succession of 26 TDMA frames, and corresponds to the 26×8 BP or 120 ms cycle used in the definition of the TACH/F and the TACH/H.

3GPP TS 45.001 V7.2.0 (2005-11)

Technical Specification

**3rd Generation Partnership Project;
Technical Specification Group GSM/EDGE
Radio Access Network;
Physical layer on the radio path;
General description
(Release 7)**



The present document has been developed within the 3rd Generation Partnership Project (3GPPTM) and may be further elaborated for the purposes of 3GPP.

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Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

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1 Scope

The present document is an introduction to the 45 series of the digital cellular telecommunications systems GSM technical specifications. It is not of a mandatory nature, but consists of a general description of the organization of the physical layer with reference to the technical specifications where each part is specified in detail. It introduces furthermore, the reference configuration that will be used throughout this series of technical specifications.

1.1 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

- [1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".
- [2] 3GPP TR 23.003: "Numbering, Addressing and Identification".
- [3] 3GPP TS 23.034: "High Speed Circuit Switched Data (HSCSD); Stage 2".
- [4] 3GPP TS 43.020: "Security-related Networks Functions".
- [5] 3GPP TS 43.022: "Functions related to Mobile Station (MS) in idle mode and group receive mode".
- [6] 3GPP TR 43.030: "Radio network planning aspects".
- [7] 3GPP TS 43.052: "Lower layers of the GSM Cordless Telephony System (CTS) radio interface; Stage 2".
- [8] 3GPP TS 43.064: "Overall description of the GPRS radio interface; Stage 2".
- [9] 3GPP TS 44.003: "Mobile Station - Base Station System (MS - BSS) Interface Channel Structures and Access Capabilities".
- [10] 3GPP TS 44.018: "Mobile radio interface layer 3 specification; Radio Resource Control Protocol".
- [11] 3GPP TS 44.021: "Rate Adaption on the Mobile Station - Base Station System (MS-BSS) Interface".
- [12] 3GPP TS 44.060: "General Packet Radio Service (GPRS); Mobile Station (MS) - Base Station System (BSS) interface; Radio Link Control/ Medium Access Control (RLC/MAC) protocol".
- [13] 3GPP TS 45.002: "Multiplexing and multiple access on the radio path".
- [14] 3GPP TS 45.003: "Channel coding".
- [15] 3GPP TS 45.004: "Modulation".
- [16] 3GPP TS 45.005: "Radio transmission and reception".
- [17] 3GPP TS 45.008: "Radio subsystem link control".
- [18] 3GPP TS 45.009: "Link adaptation".
- [19] 3GPP TS 45.010: "Radio subsystem synchronization".
- [20] 3GPP TS 45.056: "GSM Cordless Telephony System (CTS); Phase 1; CTS-FP Radio subsystem".

[21] 3GPP TR 45.902: "Flexible Layer One".

1.2 Abbreviations

Abbreviations used in the present document are listed in 3GPP TR 21.905.

2 Set of channels

The radio subsystem provides a certain number of logical channels that can be separated into two categories according to 3GPP TS 44.003, 3GPP TS 43.064 and 3GPP TS 43.052:

1) The traffic channels (TCH): they are intended to carry two types of user information streams: encoded speech and data. The following types of traffic channels are defined: Bm or full-rate (TCH/F), Lm or half-rate (TCH/H), cell broadcast (CBCH), full rate packet data (PDTCH/F) and half rate packet data (PDTCH/H) traffic channels. For the purpose of this series of technical specifications, the following traffic channels are distinguished:

- full rate speech TCH (TCH/FS);
- enhanced full rate speech TCH (TCH/EFS)
- half rate speech TCH (TCH/HS);
- adaptive full rate speech TCH (TCH/AFS);
- adaptive half rate speech TCH (TCH/AHS);
- adaptive half rate 8-PSK speech TCH (O-TCH/AHS);
- adaptive full rate wideband speech (TCH/WFS)
- adaptive full rate 8-PSK wideband speech (O-TCH/WFS)
- adaptive half rate 8-PSK wideband speech (O-TCH/WHS)
- 28,8 kbit/s full rate data E-TCH (E-TCH/F28.8);
- 32,0 kbit/s full rate data E-TCH (E-TCH/F32.0);
- 43,2 kbit/s full rate data E-TCH (E-TCH/F43.2);
- 14,4 kbit/s full rate data TCH (TCH/F14.4);
- 9,6 kbit/s full rate data TCH (TCH/F9.6);
- 4,8 kbit/s full rate data TCH (TCH/F4.8);
- 4,8 kbit/s half rate data TCH (TCH/H4.8);
- $\leq 2,4$ kbit/s full rate data TCH (TCH/F2.4);
- $\leq 2,4$ kbit/s half rate data TCH (TCH/H2.4);
- cell broadcast channel (CBCH);
- full rate packet data traffic channel (PDTCH/F);
- half rate packet data traffic channel (PDTCH/H).

Adaptive speech traffic channels are channels for which part of the radio bandwidth is reserved for transmission of in band signalling to allow in call adaptation of the speech and channel codec. 8 full rate block structures for TCH/AFS, 8 half rate block structures for O-TCH/AHS, 6 half rate block structures for TCH/AHS, 3 full rate block structures for TCH/WFS, 5 full rate block structures for O-TCH/WFS and 3 half rate block structures for O-TCH/WHS are defined.

All channels are bi-directional unless otherwise stated. Unidirectional downlink full rate channels, TCH/FD are defined as the downlink part of the corresponding TCH/F. Unidirectional uplink full rate channels are FFS.

The allocated uplink and downlink PDTCH are used independently of each other. Dependent allocation of uplink and downlink is possible.

Multislot configurations for circuit switched connections are defined as multiple (1 up to 8) full rate channels allocated to the same MS. At least one channel shall be bi-directional (TCH/F). The multislot configuration is symmetric if all channels are bi-directional (TCH/F) and asymmetric if at least one channel is unidirectional (TCH/FD).

High Speed Circuit Switched Data (HSCSD) is an example of multislot configuration, in which all channels shall have the same channel mode.

NOTE: For the maximum number of timeslots to be used for a HSCSD configuration, see 3GPP TS 23.034.

Multislot configurations for packet switched connections are defined as multiple (1 up to 8) PDTCH/Us and one PACCH for one mobile originated communication, or multiple (1 up to 8) PDTCH/Ds and one PACCH for one mobile terminated communication respectively, allocated to the same MS. In this context allocation refers to the list of PDCH that may dynamically carry the PDTCHs for that specific MS. The PACCH shall be mapped onto one PDCH carrying one PDTCH/U or PDTCH/D. That PDCH shall be indicated in the resource allocation message (see 3GPP TS 44.060). In the case of point-to-multipoint transmission for MBMS, multiple (1 up to 5) PDTCH/Ds and one PACCH can be allocated for simultaneous communication with multiple mobiles.

Multislot configurations for dual transfer mode are defined as one bi-directional, traffic channel (TCH/H, O-TCH/H, TCH/F, O-TCH/F or E-TCH/F) and one packet channel combination. The packet channel combination may consist of one PDTCH/U and one PACCH for one mobile originated communication, or multiple (1 or 2) PDTCH/Ds and one PACCH for one mobile terminated communication respectively, allocated to the same MS. The PACCH shall be mapped onto one PDCH carrying one PDTCH/U or PDTCH/D. That PDCH shall be indicated in the resource allocation message (see 3GPP TS 44.060).

An MS capable of dual transfer mode (DTM) shall support, as a minimum, DTM multislot class 5, which utilises the two-timeslot channelization method, i.e. a single TCH/F or O-TCH/F plus a single PDTCH/F. In addition, the MS supporting DTM shall support TCH/H + PDCH/F configuration with the adaptive multirate (AMR) speech coder for voice coding.

- 2) The signalling channels: these can be sub-divided into (P)BCCH ((packet) broadcast control channel), (P)CCCH ((packet) common control channel), SDCCH (stand-alone dedicated control channel), (P)ACCH ((packet) associated control channel), packet timing advance control channel (PTCCH) and CTSCCH (CTS control channel). An associated control channel is always allocated in conjunction with, either a TCH, or an SDCCH. A packet associated control channel is always allocated in conjunction to one or multiple PDTCH, concurrently assigned to one MS. Two types of ACCH for circuit switched connections are defined: continuous stream (slow ACCH) and burst stealing mode (fast ACCH). For the purpose of this series of technical specifications, the following signalling channels are distinguished:

- stand-alone dedicated control channel, four of them mapped on the same basic physical channel as the CCCH (SDCCH/4);
- stand-alone dedicated control channel, eight of them mapped on a separate basic physical channel (SDCCH/8);
- full rate fast associated control channel (FACCH/F);
- enhanced circuit switched full rate fast associated control channel (E-FACCH/F);
- half rate fast associated control channel (FACCH/H);
- full rate octal fast associated control channel (O-FACCH/F);
- half rate octal fast associated control channel (O-FACCH/H);
- slow, TCH/F, O-TCH/F or E-TCH/F associated, control channel (SACCH/TF);
- slow, TCH/F or O-TCH/F associated, control channel for enhanced power control (SACCH/TPF);
- slow, TCH/H or O-TCH/H associated, control channel (SACCH/TH);

- slow, TCH/H or O-TCH/H associated, control channel for enhanced power control (SACCH/TPH);
- slow, TCH/F, O-TCH/F or E-TCH/F associated, control channel for multislot configurations (SACCH/M);
- slow, TCH/F or O-TCH/F associated, control channel for enhanced power control in multislot configurations (SACCH/MP);
- slow, TCH/F associated, control channel for CTS (SACCH/CTS);
- slow, SDCCH/4 associated, control channel (SACCH/C4);
- slow, SDCCH/8 associated, control channel (SACCH/C8);
- packet associated control channel (PACCH);
- packet timing advance control channel (PTCCH);
- broadcast control channel (BCCH);
- packet broadcast control channel (PBCCH);
- random access channel (i.e. uplink CCCH) (RACH);
- packet random access channel (i.e. uplink PCCCH) (PRACH);
- paging channel (part of downlink CCCH) (PCH);
- packet paging channel (part of downlink PCCCH) (PPCH);
- access grant channel (part of downlink CCCH) (AGCH);
- packet access grant channel (part of downlink PCCCH) (PAGCH);
- notification channel (part of downlink CCCH) (NCH);
- CTS beacon channel (part of downlink CTSCCH) (CTSBCH-FB and CTSBCH-SB);
- CTS paging channel (part of downlink CTSCCH) (CTSPCH);
- CTS access request channel (part of uplink CTSCCH) (CTSARCH);
- CTS access grant channel (part of downlink CTSCCH) (CTSAGCH);
- enhanced inband associated control channel (E-IACCH);
- enhanced power control channel (EPCCH);
- enhanced power control channel for multislot configurations (EPCCH/M);
- packet random access channel for MBMS (MPRACH).

All associated control channels have the same direction (bi-directional or unidirectional) as the channels they are associated to. The unidirectional SACCH/MD, SACCH/MPD or EPCCH/MD are defined as the downlink part of SACCH/M, SACCH/MP or EPCCH/M respectively.

When there is no need to distinguish between different sub-categories of the same logical channel, only the generic name will be used, meaning also all the sub-categories, irrespective of modulation used (SACCH will mean all categories of SACCHs, SACCH/T will mean both the slow, TCH associated, control channels with and without enhanced power control, etc.).

The logical channels mentioned above are mapped on physical channels that are described in this set of technical specifications. The different physical channels provide for the transmission of information pertaining to higher layers according to a block structure.

3 Reference configuration

For the purpose of elaborating the physical layer specification, a reference configuration of the transmission chain is used as shown in annex A. This reference configuration also indicates which parts are dealt with in details in which technical specification. It shall be noted that only the transmission part is specified, the receiver being specified only via the overall performance requirements. With reference to this configuration, the technical specifications in the 45 series address the following functional units:

- 3GPP TS 45.002: burst building, and burst multiplexing;
- 3GPP TS 45.003: coding, reordering and partitioning, and interleaving;
- 3GPP TS 45.004: differential encoding, and modulation;
- 3GPP TS 45.005: transmitter, antenna, and receiver (overall performance).

NOTE: 3GPP TS 45.056 addresses the transmitter and receiver of the CTS-FP.

This reference configuration defines also a number of points of vocabulary in relation to the name of bits at different levels in the configuration. It must be outlined, in the case of the encrypted bits, that they are named only with respect to their position after the encryption unit, and not to the fact that they pertain to a flow of information that is actually encrypted.

4 The block structures

The different block structures are described in more detail in 3GPP TS 45.003. A summarised description appears in table 1, in terms of net bit rate, length and recurrence of blocks.

Table 1: Channel block structures

Type of channel	net bit rate (kbit/s)	block length (bits)	block recurrence (ms)
full rate speech TCH ¹	13,0	182 + 78	20
enhanced full rate speech TCH ¹	12,2	170 + 74	20
half rate speech TCH ²	5,6	95 + 17	20
Adaptive full rate speech TCH (12,2 kbit/s)	12,2	244	20
Adaptive full rate speech TCH (10,2 kbit/s)	10,2	204	20
Adaptive full rate speech TCH (7,95 kbit/s)	7,95	159	20
Adaptive full rate speech TCH (7,4 kbit/s)	7,4	148	20
Adaptive full rate speech TCH (6,7 kbit/s)	6,7	134	20
Adaptive full rate speech TCH (5,9 kbit/s)	5,9	118	20
Adaptive full rate speech TCH (5,15 kbit/s)	5,15	103	20
Adaptive full rate speech TCH (4,75 kbit/s)	4,75	95	20
Adaptive half rate speech TCH (7,95 kbit/s) ⁸	7,95	123 + 36	20
Adaptive half rate speech TCH (7,4 kbit/s) ⁸	7,4	120 + 28	20
Adaptive half rate speech TCH (6,7 kbit/s) ⁸	6,7	110 + 24	20
Adaptive half rate speech TCH (5,9 kbit/s) ⁸	5,9	102 + 16	20
Adaptive half rate speech TCH (5,15 kbit/s) ⁸	5,15	91 + 12	20
Adaptive half rate speech TCH (4,75 kbit/s) ⁸	4,75	83 + 12	20
Adaptive half rate 8-PSK speech TCH (12,2 kbit/s)	12,2	244	20
Adaptive half rate 8-PSK speech TCH (10,2 kbit/s)	10,2	204	20
Adaptive half rate 8-PSK speech TCH (7,95 kbit/s)	7,95	159	20
Adaptive half rate 8-PSK speech TCH (7,4 kbit/s)	7,4	148	20
Adaptive half rate 8-PSK speech TCH (6,7 kbit/s)	6,7	134	20
Adaptive half rate 8-PSK speech TCH (5,9 kbit/s)	5,9	118	20
Adaptive half rate 8-PSK speech TCH (5,15 kbit/s)	5,15	103	20
Adaptive half rate 8-PSK speech TCH (4,75 kbit/s)	4,75	95	20
Wideband Adaptive full rate speech TCH (12,65 kbit/s)	12,65	253	20
Wideband Adaptive full rate speech TCH (8,85 kbit/s)	8,85	177	20
Wideband Adaptive full rate speech TCH (6,60 kbit/s)	6,60	132	20
Wideband Adaptive full rate 8-PSK speech TCH (23,85 kbit/s)	23,85	477	20
Wideband Adaptive full rate 8-PSK speech TCH (15,85 kbit/s)	15,85	317	20
Wideband Adaptive full rate 8-PSK speech TCH (12,65 kbit/s)	12,65	253	20
Wideband Adaptive full rate 8-PSK speech TCH (8,85 kbit/s)	8,85	177	20
Wideband Adaptive full rate 8-PSK speech TCH (6,6 kbit/s)	6,60	132	20

(continued)

Type of channel	net bit rate (kbit/s)	block length (bits)	block recurrence (ms)
Wideband Adaptive half rate 8-PSK speech TCH (12,65 kbit/s)	12,65	253	20
Wideband Adaptive half rate 8-PSK speech TCH (8,85 kbit/s)	8,85	177	20
Wideband Adaptive half rate 8-PSK speech TCH (6,6 kbit/s)	6,60	132	20
data E-TCH (43,2 kbit/s) ³	43,5	870	20
data E-TCH (32,0 kbit/s) ³	32,0	640	20
data E-TCH (28,8 kbit/s) ³	29,0	580	20
data TCH (14,4 kbit/s) ³	14,5	290	20
data TCH (9,6 kbit/s) ³	12,0	60	5
data TCH (4,8 kbit/s) ³	6,0	60	10
data TCH ($\leq 2,4$ kbit/s) ³	3,6	36	10
PDTCH/F (CS-1)	9,05	181	-
PDTCH/F (CS-2)	13,4	268	-
PDTCH/F (CS-3)	15,6	312	-
PDTCH/F (CS-4)	21,4	428	-
PDTCH/H (CS-1)	4,525	181	-
PDTCH/H (CS-2)	6,7	268	-
PDTCH/H (CS-3)	7,8	312	-
PDTCH/H (CS-4)	10,7	428	-
PDTCH/F (MCS-1) ¹⁰	10,6	212	-
PDTCH/F (MCS-2) ¹⁰	13,0	260	-
PDTCH/F (MCS-3) ¹⁰	16,6	332	-
PDTCH/F (MCS-4) ¹⁰	19,4	388	-
PDTCH/F (MCS-5) ¹⁰	24,05	481	-
PDTCH/F (MCS-6) ¹⁰	31,25	625	-
PDTCH/F (MCS-7) ¹⁰	47,45	949	-
PDTCH/F (MCS-8) ¹⁰	57,05	1141	-
PDTCH/F (MCS-9) ¹⁰	61,85	1237	-
PDTCH/H (MCS-1) ¹⁰	5,3	212	-
PDTCH/H (MCS-2) ¹⁰	6,5	260	-
PDTCH/H (MCS-3) ¹⁰	8,3	332	-
PDTCH/H (MCS-4) ¹⁰	9,7	388	-
PDTCH/H (MCS-5) ¹⁰	12,025	481	-
PDTCH/H (MCS-6) ¹⁰	15,625	625	-
PDTCH/H (MCS-7) ¹⁰	23,725	949	-
PDTCH/H (MCS-8) ¹⁰	28,525	1141	-
PDTCH/H (MCS-9) ¹⁰	30,925	1237	-
full rate FACCH (FACCH/F)	9,2	184	20
half rate FACCH (FACCH/H)	4,6	184	40
enhanced circuit switched full rate FACCH (E-FACCH/F)	9,2	184	20
full rate octal FACCH (O-FACCH/F)	9,2	184	20
half rate octal FACCH (O-FACCH/H)	4,6	184	40
SDCCH	598/765 ($\approx 0,782$)	184	3 060/13 (235)
SACCH (with TCH) ⁴	115/300 ($\approx 0,383$)	168 + 16	480
SACCH (with SDCCH) ⁴	299/765 ($\approx 0,391$)	168 + 16	6 120/13 (≈ 471)
PACCH/F ⁷		181	
PACCH/H ⁷		181	
BCCH	598/765 ($\approx 0,782$)	184	3 060/13 (≈ 235)

(continued)

Type of channel	net bit rate (kbit/s)	block length (bits)	block recurrence (ms)
PBCCH ⁶	$s \cdot 181/120 (\approx 1,508)$	181	120
AGCH ⁵	$n \cdot 598/765 (\approx 0,782)$	184	3 060/13 (≈ 235)
PAGCH ⁷		181	
NCH ⁵	$m \cdot 598/765 (\approx 0,782)$	184	3 060/13 (≈ 235)
PCH ⁵	$p \cdot 598/765 (\approx 0,782)$	184	3 060/13 (≈ 235)
PPCH ⁷		181	
RACH ⁵	$r \cdot 26/765 (\approx 0,034)$	8	3 060/13 (≈ 235)
PRACH (8 bit Access Burst) ⁷		8	
PRACH (11 bit Access Burst) ⁷		11	
MPRACH (8 bit Access Burst) ⁷		8	
MPRACH (11 bit Access Burst) ⁷		11	
CBCH	$598/765 (\approx 0,782)$	184	3 060/13 (≈ 235)
CTSBCH-SB	$25/240 (\approx 0,104)$	25	240
CTSPCH	$184/240 (\approx 0,767)$	184	240
CTSARCH	$14 \cdot 25/240 (\approx 0,104)$	25	240
CTSAGCH	$2 \cdot 184/240 (\approx 0,767)$	184	240
<p>NOTE 1: For full rate speech, the block is divided into two classes according to the importance of the bits (182 bits for class I and 78 bits for class II). For enhanced full rate speech, the block is divided into two classes according to the importance of the bits (170 bits for class I and 74 bits for class II).</p> <p>NOTE 2: For half rate speech, the block is divided into two classes according to the importance of the bits (95 bits for class I and 17 bits for class II).</p> <p>NOTE 3: For data services, the net bit rate is the adaptation rate as defined in 3GPP TS 44.021.</p> <p>NOTE 4: On SACCH, 16 bits are reserved for control information on layer 1, and 168 bits are used for higher layers.</p> <p>NOTE 5: CCCH channels are common to all users of a cell; the total number of blocks (m, n, p, r) per recurrence period is adjustable on a cell by cell basis and depends upon the parameters (BS_CC_CHANS, BS_BCCH_SDCCH_COMB, BS_AG_BLKES_RES and NCP) broadcast on the BCCH and specified in 3GPP TS 45.002 and 3GPP TS 44.018.</p> <p>NOTE 6: The total number of PBCCH blocks (s) is adjustable on a cell by cell basis and depends upon the parameter BS_PBCCH_BLKES broadcast on the first PBCCH block and specified in 3GPP TS 45.002 and 3GPP TS 44.018.</p> <p>NOTE 7: The net bit rate for these channels in a cell can change dynamically and depends on how PDCH are configured in a cell, and upon the parameters BS_PBCCH_BLKES, BS_PAG_BLKES_RES and BS_PRACH_BLKES broadcast on the PBCCH and specified in 3GPP TS 45.002 and 3GPP TS 44.018, as well as upon how certain blocks on the PDCH are used (indicated by the message type).</p> <p>NOTE 8: For adaptive half rate speech, the blocks are divided into two classes according to the importance of the bits (the first number in the block length corresponds to the class I bits, the second number corresponds to the class II bits).</p> <p>NOTE 9: CTSBCH, CTSARCH, CTSPCH and CTSAGCH are only used in CTS.</p> <p>NOTE 10: For EGPRS PDTCH, the block length in bits excludes the USF bits (downlink traffic) and all the error-check bits.</p>			

5 Multiple access and timeslot structure

The access scheme is Time Division Multiple Access (TDMA) with eight basic physical channels per carrier. The carrier separation is 200 kHz. A physical channel is therefore defined as a sequence of TDMA frames, a time slot number (modulo 8) and a frequency hopping sequence.

The basic radio resource is a time slot lasting $\approx 576,9 \mu\text{s}$ (15/26 ms) and transmitting information at a modulation rate of $\approx 270.833 \text{ kbit/s}$ (1 625/6 kbit/s). This means that the time slot duration, including guard time, is 156,25 bit duration.

We shall describe successively the time frame structures, the time slot structures and the channel organization. The appropriate specifications will be found in 3GPP TS 45.002.

5.1 Hyperframes, superframes and multiframes

A diagrammatic representation of all the time frame structures is in figure 1. The longest recurrent time period of the structure is called hyperframe and has a duration of 3 h 28 mn 53 s 760 ms (or 12 533,76 s). The TDMA frames are numbered modulo this hyperframe (TDMA frame number, or FN, from 0 to 2 715 647). This long period is needed to support cryptographic mechanisms defined in 3GPP TS 43.020.

One hyperframe is subdivided in 2 048 superframes which have a duration of 6,12 seconds. The superframe is the least common multiple of the time frame structures. The superframe is itself subdivided in multiframes; four types of multiframes exist in the system:

- a 26- multiframe (51 per superframe) with a duration of 120 ms, comprising 26 TDMA frames. This multiframe is used to carry TCH (and SACCH/T) and FACCH;
- a 51- multiframe (26 per superframe) with a duration of $\approx 235,4$ ms (3 060/13 ms), comprising 51 TDMA frames. This multiframe is used to carry BCCH, CCCH (NCH, AGCH, PCH and RACH) and SDCCH (and SACCH/C).
- a 52-multiframe (25,5 per superframe) with a duration of 240 ms, comprising 52 TDMA frames. This multiframe is used to carry PBCCH, PCCCH (PAGCH, PPCH and PRACH), PACCH, PDTCH, PTCCH and MPRACH. The 52-multiframe is not shown in Figure 1, but can be seen as two 26-multiframes, with TDMA frames numbered from 0 to 51. For Compact, this 52-multiframe (51 per superframe) is used to carry CFCCCH, CSCH, CPBCCH, CPCCCH (CPAGCH, CPPCH, and CPRACH), PACCH, PDTCH, and PTCCH.
- a 52-multiframe (25,5 per superframe) for CTS, with a duration of 240 ms, comprising 52 TDMA frames. This multiframe is used to carry CTSCCH (CTSBCH, CTSPCH, CTSARCH and CTSAGCH). The 52-multiframe for CTS is shown in Figure 2b.

A TDMA frame, comprising eight time slots has a duration of $\approx 4,62$ (60/13) ms.

5.2 Time slots and bursts

The time slot is a time interval of $\approx 576,9$ μ s (15/26 ms), that is 156,25 symbol¹ duration, and its physical content is called a burst. Four different types of bursts exist in the system. A diagram of these bursts appears in figure 1.

- normal burst (NB): this burst is used to carry information on traffic and control channels, except for RACH, PRACH, and CPRACH. It contains 116 encrypted symbol and includes a guard time of 8,25 symbol duration ($\approx 30,46$ μ s);
- frequency correction burst (FB): this burst is used for frequency synchronization of the mobile. It is equivalent to an unmodulated carrier, shifted in frequency, with the same guard time as the normal burst. It is broadcast together with the BCCH. The repetition of FBs is also named frequency correction channel (FCCH). For Compact, FB is broadcast together with the CPBCCH and the repetition of FBs is also named Compact frequency correction channel (CFCCCH). In CTS, the frequency correction burst is broadcast in the CTSBCH-FB channel;
- synchronization burst (SB): this burst is used for time synchronization of the mobile. It contains a long training sequence and carries the information of the TDMA frame number (FN) and base station identity code (BSIC, see 3GPP TR 23.003). It is broadcast together with the frequency correction burst. The repetition of synchronization bursts is also named synchronization channel (SCH). For Compact, the repetition of synchronization bursts is also named Compact synchronization channel (CSCH). In CTS, the synchronization burst is used for the CTSBCH-SB and the CTSARCH, and it carries different information depending on the channel using it;
- access burst (AB): this burst is used for random access and is characterized by a longer guard period (68,25 bit duration or 252 μ s) to cater for burst transmission from a mobile which does not know the timing advance at the first access (or after handover). This allows for a distance of 35 km. In exceptional cases of cell radii larger than 35 km, some possible measures are described in 3GPP TR 43.030. The access burst is used in the (P)RACH, CPRACH and MPRACH, after handover, on the uplink of a channel used for a voice group call in order to request the use of that uplink, as well as on the uplink of the PTCCH to allow estimation of the timing advance for MS in packet transfer mode.

¹ One symbol is either one or three bits depending on the modulation used: GMSK or 8PSK.

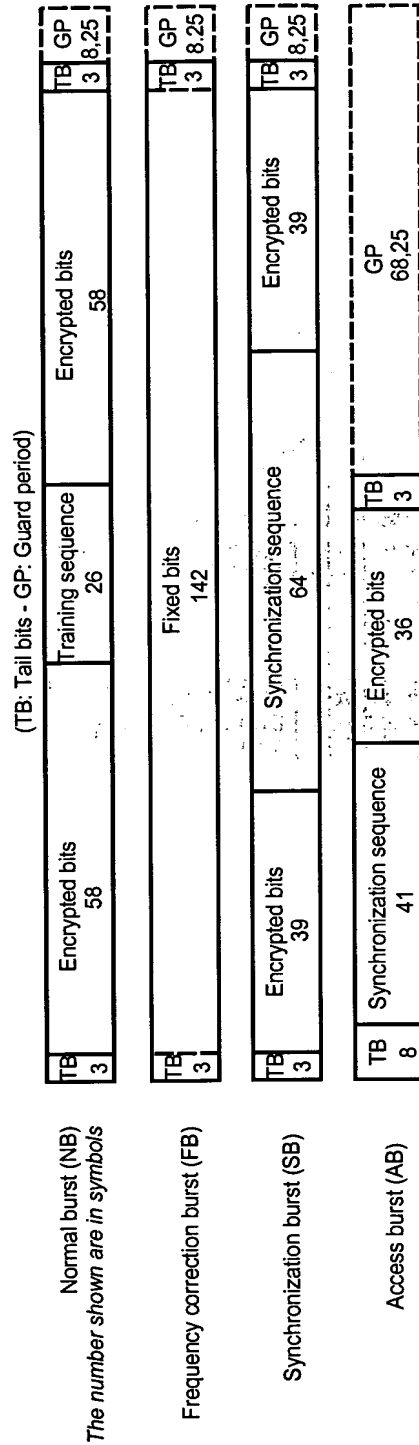
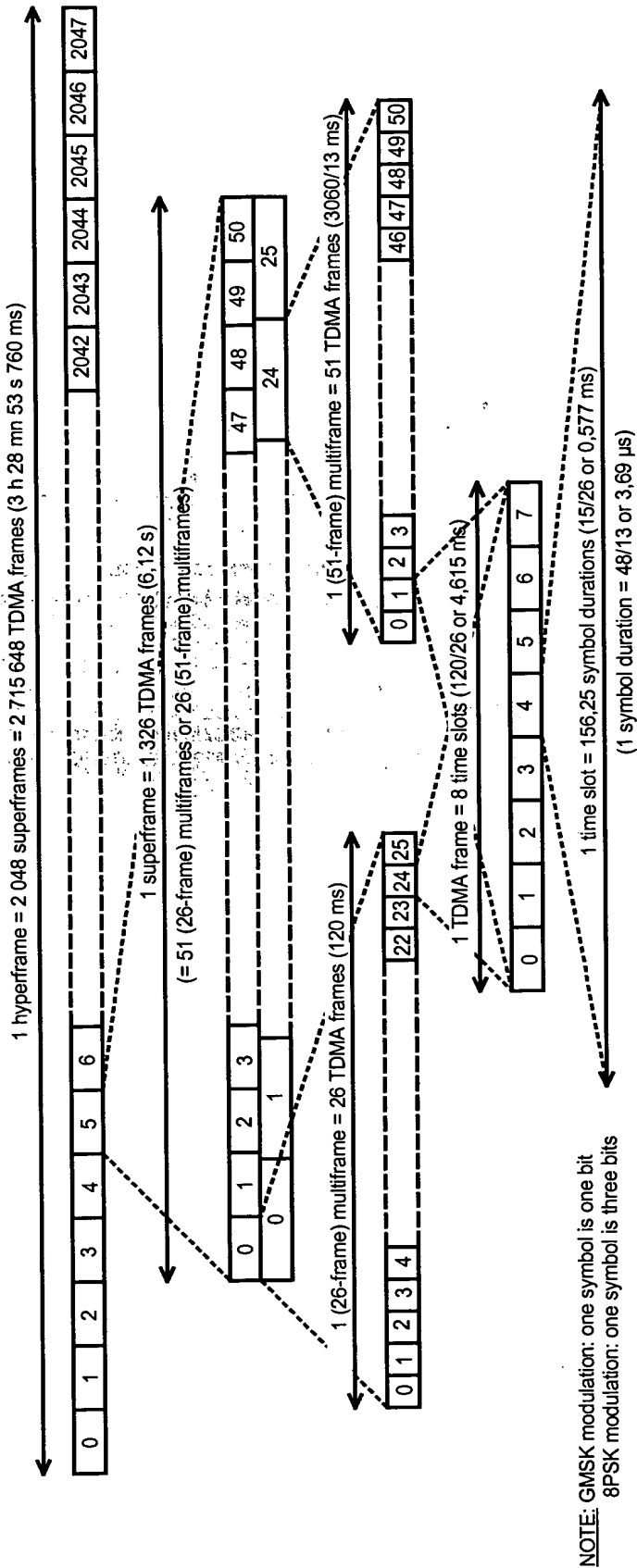


Figure 1: Time frames time slots and bursts

5.3 Channel organization

The channel organization for the traffic channels (TCH), FACCHs and SACCH/T uses the 26-frame multiframe. It is organized as described in figure 2, where only one time slot per TDMA frame is considered.

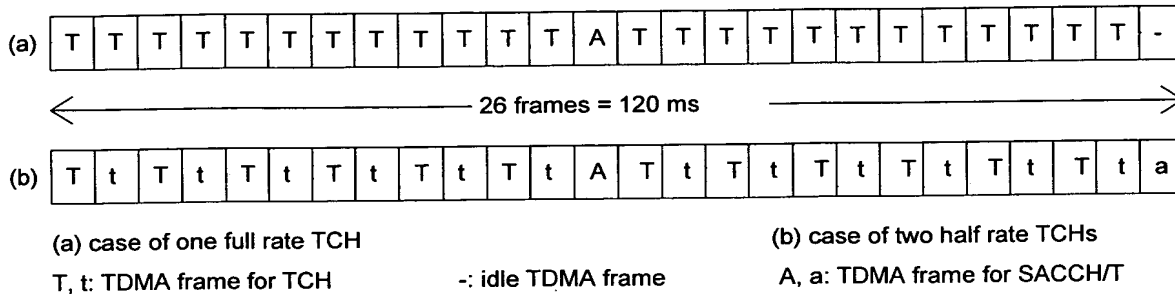


Figure 2: Traffic channel organization

The FACCH is transmitted by pre-empting half or all of the information bits of the bursts of the TCH to which it is associated (see 3GPP TS 45.003).

The channel organization for the control channels (except FACCHs and SACCH/T) uses the 51-frame multiframe. It is organized in the downlink and uplink as described in figure 3.

The channel organization for packet data channels uses the 52- multiframe. Full rate packet data channels are organized as described in figure 2a1. Half rate packet data channels can be organized as described in figure 2a2.

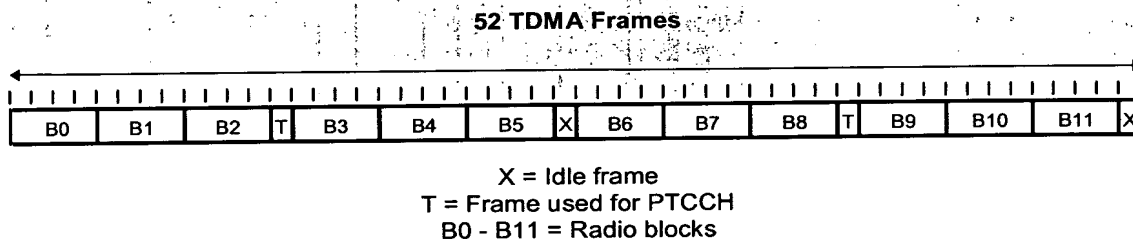


Figure 2a1: 52- multiframe for PDCH/Fs

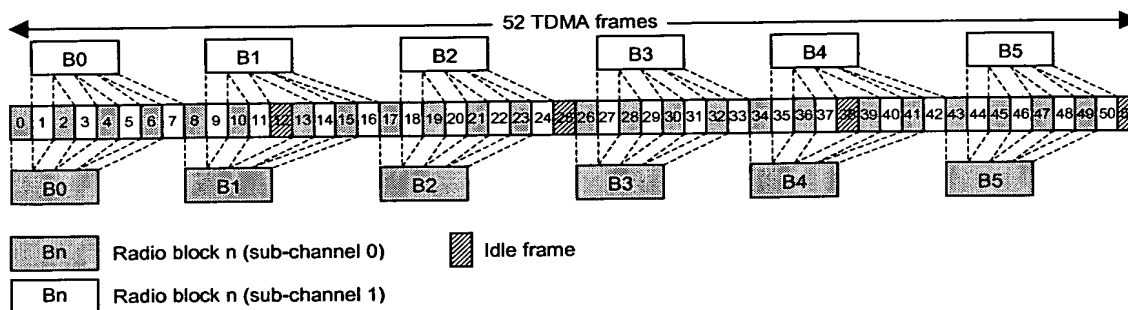


Figure 2a2: 52- multiframe for PDCH/Hs

The channel organization for CTS control channels uses the 52-multiframe. It is organized as described in figure 2b.

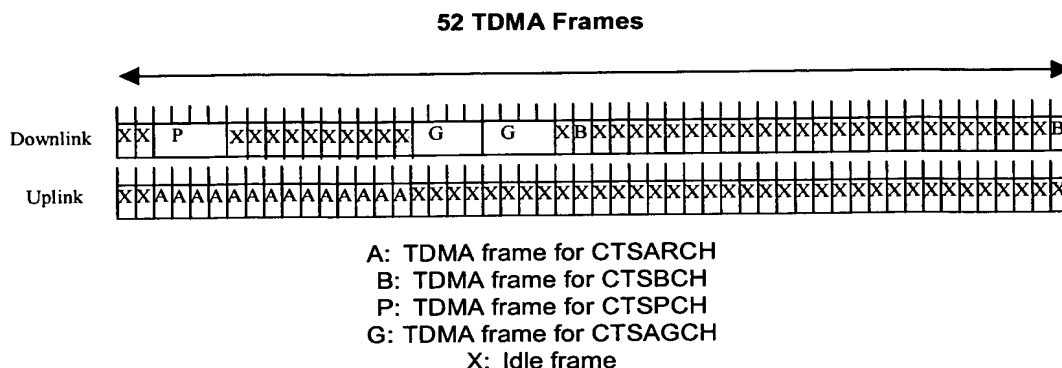


Figure 2b: 52-multiframe for CTS

6 Frequency hopping capability

The frequency hopping capability is optionally used by the network operator on all or part of its network. The main advantage of this feature is to provide diversity on one transmission link (especially to increase the efficiency of coding and interleaving for slowly moving mobile stations) and also to average the quality on all the communications through interferers diversity. It is implemented on all mobile stations.

The principle of slow frequency hopping is that every mobile transmits its time slots according to a sequence of frequencies that it derives from an algorithm. The frequency hopping occurs between time slots and, therefore, a mobile station transmits (or receives) on a fixed frequency during one time slot ($\approx 577 \mu\text{s}$) and then must hop before the time slot on the next TDMA frame. Due to the time needed for monitoring other base stations the time allowed for hopping is approximately 1 ms, according to the receiver implementation. The receive and transmit frequencies are always duplex frequencies.

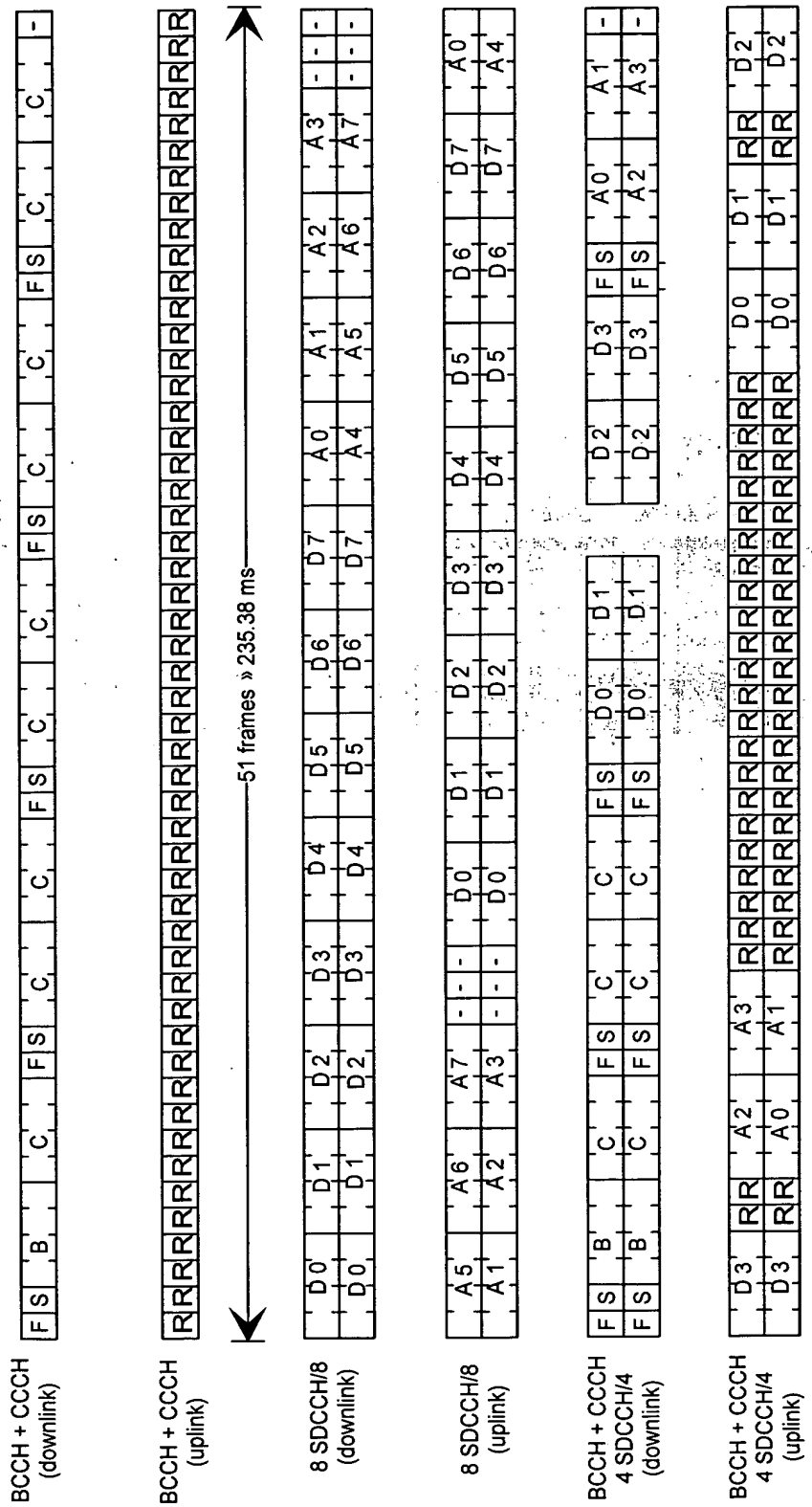
The frequency hopping sequences are orthogonal inside one cell (i.e. no collisions occur between communications of the same cell), and independent from one cell to an homologue cell (i.e. using the same set of RF channels, or cell allocation). The hopping sequence is derived by the mobile from parameters broadcast at the channel assignment, namely, the mobile allocation (set of frequencies on which to hop), the hopping sequence number of the cell (which allows different sequences on homologue cells) and the index offset (to distinguish the different mobiles of the cell using the same mobile allocation). The non-hopping case is included in the algorithm as a special case. The different parameters needed and the algorithm are specified in 3GPP TS 45.002.

In case of multi band operation frequency hopping channels in different bands of operation, e.g. between channels in GSM and DCS, is not supported. Frequency hopping within each of the bands supported shall be implemented in the mobile station.

It must be noted that the basic physical channel supporting the BCCH does not hop.

For COMPACT, frequency hopping is not permitted on CPBCCH or CPCCCH for a specific amount of blocks. On other frequency hopping channels, a reduced mobile allocation is used on the corresponding blocks.

In CTS, the frequency hopping capability shall be used. The frequency hopping sequences are independently chosen by each CTS-FP. The hopping sequence is derived by the CTS-MS from parameters transmitted during the attachment procedure. The different parameters needed and the algorithm are specified in 3GPP TS 45.002. It must be noted that the basic physical channels supporting the CTSBCH and some other particular channels do not hop (see 3GPP TS 45.002).



- F: TDMA frame for frequency correction burst
- B: TDMA frame for BCCH
- D: TDMA frame for SDCCH
- R: TDMA frame for RACH
- S: TDMA frame for synchronization burst
- C: TDMA frame for CCCH
- A: TDMA frame for SACCH/C

Figure 3: Channel organization in the 51-frame multiframe

7 Coding and interleaving

7.1 General

A brief description of the coding schemes that are used for the logical channels mentioned in clause 2, plus the synchronization channel (SCH, see subclause 5.2), is made in the following tables. For all the types of channels the following operations are made in this order:

- external coding (block coding);
- internal coding (convolutional coding);
- interleaving.

After coding the different channels (except RACH, SCH, CTSBCH-SB and CTSARCH) are constituted by blocks of coded information bits plus coded header (the purpose of the header is to distinguish between TCH and FACCH blocks). These blocks are interleaved over a number of bursts. The block size and interleaving depth are channel dependent. All these operations are specified in 3GPP TS 45.003.

For the adaptive speech traffic channels a signaling codeword is attached to the block of coded information bits before interleaving. The signaling codeword is a block code representation of a 2-bits inband information word (rate $\frac{1}{4}$ for the adaptive full rate speech traffic channels, $\frac{1}{2}$ for the adaptive half rate speech traffic channels, rate $\frac{1}{6}$ for the adaptive half rate 8-PSK speech and 8-PSK wideband speech traffic channels, and rate $\frac{1}{12}$ for the adaptive full rate 8-PSK wideband speech traffic channels).

Type of channel	bits/block data+parity+tail1	convolutional code rate	coded bits per block	interleaving depth
TCH/FS			456	8
class I ²	182 + 3 + 4	$\frac{1}{2}$	378	
class II	78 + 0 + 0	-	78	
TCH/EFS			456	8
class I ²	170 + 15 + 4	$\frac{1}{2}$	378	
class II	74 + 4 + 0	-	78	
TCH/HS			228	4
class I ³	95+3+6	104/211	211	
class II	17+0+0		17	
TCH/AFS12.2 ⁴			456	8
Class I ⁵	244 + 6 + 4	127/224	448	
TCH/AFS10.2 ⁴			456	8
Class I ⁶	204 + 6 + 4	107/224	448	
TCH/AFS7.95 ⁴			456	8
Class I ⁷	159 + 6 + 6	171/448	448	
TCH/AFS7.4 ⁴			456	8
Class I ⁸	148 + 6 + 4	79/224	448	
TCH/AFS6.7 ⁴			456	8
Class I ⁹	134 + 6 + 4	9/28	448	
TCH/AFS5.9 ⁴			456	8
Class I ¹⁰	118 + 6 + 6	65/224	448	
TCH/AFS5.15 ⁴			456	8
Class I ¹¹	103 + 6 + 4	113/448	448	
TCH/AFS4.75 ⁴			456	8
Class I ¹²	95 + 6 + 6	107/448	448	
TCH/AHS7.95 ¹³			228	4
Class I ¹⁴	123 + 6 + 4	133/188	188	
Class II	36+0+0		36	
TCH/AHS7.4 ¹³			228	4
Class I ¹⁵	120 + 6 + 4	65/98	196	
Class II	28+0+0		28	
TCH/AHS6.7 ¹³			228	4
Class I ¹⁶	110 + 6 + 4	3/5	200	
Class II	24+0+0		24	
TCH/AHS5.9 ¹³			228	4
Class I ¹⁷	102 + 6 + 4	7/13	208	
Class II	16+0+0		16	
TCH/AHS5.15 ¹³			228	4
Class I ¹⁸	91 + 6 + 4	101/212	212	
Class II	12+0+0		12	
TCH/AHS4.75 ¹³			228	4
Class I ¹⁹	83 + 6 + 6	95/212	212	
Class II	12+0+0		12	

(continued)

(continued)				
Type of channel	bits/block data+parity+tail1	convolutional code rate	coded bits per block	interleaving depth
TCH/WFS12.65 ⁴ Class I ²³	253 + 6 + 4	263/448	456 448	8
TCH/WFS8.85 ⁴ Class I ²⁴	177 + 6 + 4	187/448	456 448	8
TCH/WFS6.6 ⁴ Class I ²⁵	132 + 8 + 4	9/28	456 448	8
O-TCH/WFS23.85 ²⁷ Class I ²³	477 + 6 + 6	163/448	1368 1344	8
O-TCH/WFS15.85 ²⁷ Class I ²³	317 + 6 + 6	47/192	1368 1344	8
O-TCH/WFS12.65 ²⁷ Class I ²³	253 + 6 + 6	14/71	1368 1344	8
O-TCH/WFS8.85 ²⁷ Class I ²⁴	177 + 6 + 6	9/64	1368 1344	8
O-TCH/WFS6.6 ²⁷ Class I ²⁸	132 + 6 + 6	3/28	1368 1344	8
O-TCH/WHS12.65 ²⁶ Class I ²³	253 + 6 + 6	265/672	684 672	4
O-TCH/WHS8.85 ²⁶ Class I ²⁴	177 + 6 + 6	9/32	684 672	4
O-TCH/WHS6.6 ²⁶ Class I ²⁸	132 + 6 + 6	3/14	684 672	4
O-TCH/AHS12.2 ²⁶ Class I ⁵	244 + 6 + 6	8/21	684 672	4
O-TCH/AHS10.2 ²⁶ Class I ⁶	204 + 6 + 6	9/28	684 672	4
O-TCH/AHS7.95 ²⁶ Class I ⁷	159 + 6 + 6	57/224	684 672	4
O-TCH/AHS7.4 ²⁶ Class I ⁸	148 + 6 + 6	5/21	684 672	4
O-TCH/AHS6.7 ²⁶ Class I ⁹	134 + 6 + 6	73/336	684 672	4
O-TCH/AHS5.9 ²⁶ Class I ¹⁰	118 + 6 + 6	65/336	684 672	4
O-TCH/AHS5.15 ²⁶ Class I ¹¹	103 + 6 + 6	115/672	684 672	4
O-TCH/AHS4.75 ²⁶ Class I ¹²	95 + 6 + 6	107/672	684 672	4
TCH/F14.4	290 + 0 + 4	294/456	294/456	19
TCH/F9.6	4*60 + 0 + 4	244/456	456	19
TCH/F4.8	60 + 0 + 16	1/3	228	19
TCH/H4.8	4*60 + 0 + 4	244/456	456	19
TCH/F2.4	72 + 0 + 4	1/6	456	8
TCH/H2.4	72 + 0 + 4	1/3	228	19

(continued)

(continued)				
FACCH/F	184 + 40 + 4	$\frac{1}{2}$	456	8
E-FACCH/F	184 + 40 + 4	$\frac{1}{2}$	456	4
FACCH/H	184 + 40 + 4	$\frac{1}{2}$	456	6
O-FACCH/F	184 + 40 + 6	$\frac{1}{6}$	1368	8
O-FACCH/H	184 + 40 + 6	$\frac{1}{6}$	1368	6
SDCCHs SACCHs ²⁰				
BCCH NCH AGCH				
PCH				
CBCH	184 + 40 + 4	$\frac{1}{2}$	456	4
SACCH/TP	184 + 18 + 6	$\frac{1}{2}$	456	4
SACCH/MP	+ 40 ²¹			
E-IACCH	3	$\frac{1}{8}$ ²²	24	4
EPCCH	3	$\frac{1}{4}$ ²²	12	1
RACH	8 + 6 + 4	$\frac{1}{2}$	36	1
SCH	25 + 10 + 4	$\frac{1}{2}$	78	1
CTSBCH-SB	25 + 10 + 4	$\frac{1}{2}$	78	1
CTSPCH	184 + 40 + 4	$\frac{1}{2}$	456	4
CTSARCH	25 + 10 + 4	$\frac{1}{2}$	78	1
CTSAGCH	184 + 40 + 4	$\frac{1}{2}$	456	4

(continued)

- NOTE 1: The tail bits mentioned here are the tail bits of the convolutional code.
- NOTE 2: The 3 parity bits for TCH/FS detect an error on 50 bits of class I.
- NOTE 3: The 3 parity bits for TCH/HS detect an error on 22 bits of class I.
- NOTE 4: For TCH/AFS and TCH/WFS an 8 bits in band signalling codeword is attached to the block of coded information before interleaving.
A dedicated block structure to carry the comfort noise information associated with the adaptive full rate speech traffic channels is also specified in 3GPP TS 45.003.
- NOTE 5: The 6 parity bits for TCH/AFS12.2 and O-TCH/AHS12.2 detect an error on 81 bits of class I.
- NOTE 6: The 6 parity bits for TCH/AFS10.2 and O-TCH/AHS10.2 detect an error on 65 bits of class I.
- NOTE 7: The 6 parity bits for TCH/AFS7.95 and O-TCH/AHS7.95 detect an error on 75 bits of class I.
- NOTE 8: The 6 parity bits for TCH/AFS7.4 and O-TCH/AHS7.4 detect an error on 61 bits of class I.
- NOTE 9: The 6 parity bits for TCH/AFS6.7 and O-TCH/AHS6.7 detect an error on 55 bits of class I.
- NOTE 10: The 6 parity bits for TCH/AFS5.9 and O-TCH/AHS5.9 detect an error on 55 bits of class I.
- NOTE 11: The 6 parity bits for TCH/AFS5.15 and O-TCH/AHS5.15 detect an error on 49 bits of class I.
- NOTE 12: The 6 parity bits for TCH/AFS4.75 and O-TCH/AHS4.75 detect an error on 39 bits of class I.
- NOTE 13: For TCH/AHS a 4 bits in band signalling codeword is attached to the block of coded information before interleaving.
A dedicated block structure to carry the comfort noise information associated with the adaptive half rate speech traffic channels is also specified in 3GPP TS 45.003.
- NOTE 14: The 6 parity bits for TCH/AHS7.95 detect an error on 67 bits of class I.
- NOTE 15: The 6 parity bits for TCH/AHS7.4 detect an error on 61 bits of class I.
- NOTE 16: The 6 parity bits for TCH/AHS6.7 detect an error on 55 bits of class I.
- NOTE 17: The 6 parity bits for TCH/AHS5.9 detect an error on 55 bits of class I.
- NOTE 18: The 6 parity bits for TCH/AHS5.15 detect an error on 49 bits of class I.
- NOTE 19: The 6 parity bits for TCH/AHS4.75 detect an error on 39 bits of class I.
- NOTE 20: with the exception of SACCH/TP and SACCH/MP
- NOTE 21: 40 uncoded dummy bits are inserted for the mapping of the enhanced power control signalling
- NOTE 22: block code is applied
- NOTE 23: The 6 parity bits for TCH/WFS12.65, O-TCH/WFS23.85, O-TCH/WFS15.85, O-TCH/WFS12.65 and O-TCH/WFS12.65 detect an error on 72 bits of class I.
- NOTE 24: The 6 parity bits for TCH/WFS8.85, O-TCH/WFS8.85 and O-TCH/WFS8.85 detect an error on 64 bits of class I.
- NOTE 25: The 8 parity bits for TCH/WFS6.60 detect an error on 54 bits of class I.
- NOTE 27: For O-TCH/WFS a 24 bits in band signalling codeword is attached to the block of coded information before interleaving.
A dedicated block structure to carry the comfort noise information associated with the adaptive full rate 8PSK wideband speech traffic channels is also specified in 3GPP TS 45.003.
- NOTE 28: The 6 parity bits for O-TCH/WFS6.6 and O-TCH/WFS6.6 detect an error on 54 bits of class I.

Type of channel	bits/block data+parity+tail1	Reed-Solomon code rate	convolutional code rate	coded bits per block	interleaving depth
E-TCH/F43.2	870 + 0 + 6	N/A	876/1368	1368	19
E-TCH/F32.0	640 + 0 + 6	N/A	646/1392	1392	12
E-TCH/F28.8	580 + 0 + 6	73/85	686/1368	1368	19

7.2 Packet Traffic and Control Channels

All packet traffic and control channels, except PRACH, use rectangular interleaving of one Radio Block over four bursts in consecutive TDMA frames.

7.2.1 Channel coding for PDTCH

7.2.1.1 Channel coding for GPRS PDTCH

Four different coding schemes, CS-1 to CS-4, are defined for the GPRS Radio Blocks carrying RLC data blocks. For the Radio Blocks carrying RLC/MAC Control blocks code CS-1 is always used. The exceptions are messages that use

the existing Access Burst (see 3GPP TS 45.003, e.g. Packet Channel Request). An additional coding scheme is defined for the Access Burst that includes 11 information bits.

The first step of the coding procedure is to add a Block Check Sequence (BCS) for error detection. For CS-1 - CS-3, the second step consists of pre-coding USF (except for CS-1), adding four tail bits and a convolutional coding for error correction that is punctured to give the desired coding rate. For CS-4 there is no coding for error correction.

The details of the codes are shown in the table below, including:

- the length of each field;
- the number of coded bits (after adding tail bits and convolutional coding);
- the number of punctured bits;
- the data rate, including the RLC header and RLC information.

Scheme	Code rate	USF	Pre-coded USF	Radio Block excl. USF and BCS	BCS	Tail	Coded bits	Punctured bits
CS-1	$\frac{1}{2}$	3	3	181	40	4	456	0
CS-2	$\approx 2/3$	3	6	268	16	4	588	132
CS-3	$\approx 3/4$	3	6	312	16	4	676	220
CS-4	1	3	12	428	16	-	456	-

CS-1 is the same coding scheme as specified for SDCCH. It consists of a half rate convolutional code for FEC and a 40 bit FIRE code for BCS (and optionally FEC). CS-2 and CS-3 are punctured versions of the same half rate convolutional code as CS-1 for FEC. CS-4 has no FEC.

The USF has 8 states, which are represented by a binary 3 bit field in the MAC Header.

All coding schemes are mandatory for MSs supporting GPRS. Only CS-1 is mandatory for the network.

7.2.1.2 Channel coding for EGPRS PDTCH

Nine different modulation and coding schemes, MCS-1 to MCS-9, are defined for the EGPRS Radio Blocks (4 bursts, 20ms) carrying RLC data blocks. For the Radio Blocks carrying RLC/MAC Control blocks code CS-1 is always used. The exceptions are messages that use the existing Access Burst (see 3GPP TS 45.003, e.g. Packet Channel Request). An additional coding scheme is defined for the Access Burst that includes 11 information bits.

To ensure strong header protection, the header part of the Radio Block is independently coded from the data part of the Radio Block (8 bit CRC calculated over the header -excl. USF- for error detection, followed by rate 1/3 convolutional coding –and eventually puncturing- for error correction).

The MCSs are divided into different families A, B and C. Each family has a different basic unit of payload (see 3GPP TS 43.064). Different code rates within a family are achieved by transmitting a different number of payload units within one Radio Block. For families A and B, 1, 2 or 4 payload units are transmitted, for family C, only 1 or 2 payload units are transmitted.

When 4 payload units are transmitted (MCS-7, MCS-8 and MCS-9), these are splitted into two separate RLC blocks (i.e. with separate sequence numbers and block check sequences).

The first step of the coding procedure is to add a Block Check Sequence (BCS) for error detection.

The second step consists of adding six tail bits (TB) and a 1/3 rate convolutional coding for error correction that is punctured to give the desired coding rate.

The USF has 8 states, which are represented by a binary 3 bit field in the MAC Header. The USF is encoded to 12 symbols similarly to GPRS, (12 bits for GMSK modes and 36 bits for 8PSK modes).

MSs supporting EGPRS shall support MCS-1 to MCS-9 in downlink and MCS-1 to MCS-4 in uplink. In case an MS supporting EGPRS is 8-PSK capable in uplink, it shall also support MCS-5 to MCS-9 in uplink. A network supporting EGPRS may support only some of the MCSs.

The details of the EGPRS coding schemes are shown in the table below. An exhaustive description of the EGPRS coding schemes can be found in 3GPP TS 45.003.

Coding parameters for the EGPRS coding schemes

Scheme	Code rate	Header Code rate	Modulation	RLC blocks per Radio Block (20ms)	Raw Data within one Radio Block	Family	BCS	Tail payload	HCS	Data rate kb/s
MCS-9	1,0	0,36	8PSK	2	2x592	A	2x12	2x6	8	59,2
MCS-8	0,92	0,36		2	2x544	A				54,4
MCS-7	0,76	0,36		2	2x448	B				44,8
MCS-6	0,49	1/3		1	592 48+544	A	12	6		29,6 27,2
MCS-5	0,37	1/3		1	448	B				22,4
MCS-4	1,0	0,53	GMSK	1	352	C				17,6
MCS-3	0,85	0,53		1	296 48+248 and 296	A				14,8 13,6
MCS-2	0,66	0,53		1	224	B				11,2
MCS-1	0,53	0,53		1	176	C				8,8

Note: The italic captions indicate the 6 octets of padding when retransmitting MCS-8 block with MCS-3 or MCS-6. For MCS-3, the 6 octets of padding are sent every second block (see 3GPP TS 44.060).

7.2.2 Channel coding for PACCH, PBCCH, PAGCH, PPCH, CPBCCH, CPAGCH, CPPCH, and CSCH

The channel coding for the PACCH, PBCCH, PAGCH, PPCH, CPBCCH, CPAGCH, and CPPCH is corresponding to the coding scheme CS-1. The channel coding for the CSCH is identical to SCH.

7.2.3 Channel Coding for the PRACH and MPRACH

Two types of packet random access burst may be transmitted on the PRACH and MPRACH: an 8 information bits random access burst or an 11 information bits random access burst called the extended packet random access burst. The MS shall support both random access bursts. The channel coding used for the burst carrying the 8 data bit packet random access uplink message is identical to the coding of the random access burst on the RACH. The channel coding used for the burst carrying the 11 data bit packet random access uplink message is a punctured version of the coding of the random access burst on the RACH.

8 Modulations

The modulation scheme may be either gaussian MSK (GMSK) with $BT = 0,3$ or 8-PSK, depending on the type of channel. As already mentioned the modulation rate is $1\ 625/6$ ksymbol/s ($\approx 270,83$ ksymbol/s). This scheme is specified in detail in 3GPP TS 45.004.

9 Transmission and reception

The modulated stream is then transmitted on a radio frequency carrier. The frequency bands and channel arrangements are the following:

i) T-GSM 380 band:

- for T-GSM 380, the system is required to operate in the following band:
- 380,2 MHz to 389,8 MHz: mobile transmit, base receive;
- 390,2 MHz to 399,8 MHz base transmit, mobile receive.

ii) T-GSM 410 band:

- for T-GSM 410, the system is required to operate in the following band:
- 410,2 MHz to 419,8 MHz: mobile transmit, base receive;
- 420,2 MHz to 429,8 MHz base transmit, mobile receive.

iii) GSM 450 Band;

For GSM 450, the system is required to operate in the following frequency band:

- 450,4 – 457,6 MHz: mobile transmit, base receive;
- 460,4 – 467,6 MHz: base transmit, mobile receive;

iv) GSM 480 Band;

For GSM 480, the system is required to operate in the following frequency band:

- 478,8 – 486 MHz: mobile transmit, base receive;
- 488,8 – 496 MHz: base transmit, mobile receive;

v) GSM 710 Band;

For GSM 710, the system is required to operate in the following frequency band:

- 728 – 746 MHz: mobile transmit, base receive;
- 698 – 716 MHz: base transmit, mobile receive;

vi) GSM 750 Band;

For GSM 750, the system is required to operate in the following frequency band:

- 777 – 792 MHz: mobile transmit, base receive;
- 747 – 762 MHz: base transmit, mobile receive;

vii) T-GSM 810 Band;

For T-GSM 810, the system is required to operate in the following band:

- 806 - 821 MHz: mobile transmit, base receive
- 851 - 866 MHz: base transmit, mobile receive

viii) GSM 850 Band;

For 850, the system is required to operate in the following band:

- 824 - 849 MHz: mobile transmit, base receive
- 869 - 894 MHz: base transmit, mobile receive

ix) Standard or primary GSM 900 Band, P-GSM;

For Standard GSM 900 Band, the system is required to operate in the following frequency band:

890 - 915 MHz: mobile transmit, base receive

935 - 960 MHz: base transmit, mobile receive

x) Extended GSM 900 Band, E-GSM (includes Standard GSM 900 band);

For Extended GSM 900 Band, the system is required to operate in the following frequency band:

880 - 915 MHz: mobile transmit, base receive

925 - 960 MHz: base transmit, mobile receive

xi) Railways GSM 900 Band, R-GSM (includes Standard and Extended GSM 900 Band);

For Railways GSM 900 Band, the system is required to operate in the following frequency band:

876 - 915 MHz: mobile transmit, base receive

921 - 960 MHz: base transmit, mobile receive

xii) T-GSM 900 Band;

For T-GSM 900 band, the system is required to operate in the following frequency band:

- 870.4 MHz to 876 MHz: mobile transmit, base receive;

- 915.4 MHz to 921 MHz: base transmit, mobile receive.

xiii) DCS 1 800 Band;

For DCS 1 800, the system is required to operate in the following frequency band:

1 710 - 1 785 MHz: mobile transmit, base receive

1 805 - 1 880 MHz: base transmit, mobile receive

xiv) PCS 1900 Band;

For PCS 1900, the system is required to operate in the following frequency band;

1850-1910 MHz: mobile transmit, base receive

1930-1990 MHz: base transmit, mobile receive

NOTE 1: The term GSM 400 is used for any GSM system, which operates in any 400 MHz band including T-GSM 380.

NOTE 2: The term GSM 700 is used for any GSM system, which operates in any 700 MHz band.

NOTE 3: The term GSM 850 is used for any GSM system, which operates in any 850 MHz band but excluding T-GSM 810.

NOTE 4: The term GSM 900 is used for any GSM system, which operates in any 900 MHz band.

NOTE 5: The BTS may cover a complete band, or the BTS capabilities may be restricted to a subset only, depending on the operator needs.

Operators may implement networks on a combination of the frequency bands above to support multi band mobile stations.

The RF channel spacing is 200 kHz, allowing for 41 (T-GSM 380), 41 (T-GSM 410), 35 (GSM 450), 35 (GSM 480), 89 (GSM 710), 74 (GSM 750), 74 (T-GSM 810), 124 (GSM 850), 194 (GSM 900), 27 (T-GSM 900), 374 (DCS 1 800) and 299 (PCS 1900) radio frequency channels, thus leaving a guard band of 200 kHz at each end of the sub-bands.

The specific RF channels, together with the requirements on the transmitter and the receiver will be found in 3GPP TS 45.005 and in 3GPP TS 45.056 for the CTS-FP.

In order to allow for low power consumption for different categories of mobiles (e.g. vehicle mounted, hand-held, ...), different power classes have been defined. For GSM 400, GSM 700, T-GSM 810, GSM 850 and GSM 900 there are four power classes with the maximum power class having 8 W peak output power (ca 1 W mean output power) and the minimum having 0,8 W peak output power. For DCS 1 800 there are three power classes of 4 W peak output power, 1 W peak output power (ca 0,125 W mean) and 0,25 W peak output power. For PCS 1900 there are three power classes of 2 watts, 1 watt and 0,25 watt peak output power.

Multi band mobile stations may have any combinations of the allowed power classes for each of the bands supported.

The power classes are specified in 3GPP TS 45.005 and in 3GPP TS 45.056 for CTS-FP.

The requirements on the overall transmission quality together with the measurement conditions are also in 3GPP TS 45.005 and in 3GPP TS 45.056 for CTS-FP.

10 Other layer 1 functions

The transmission involves other functions. These functions may necessitate the handling of specific protocols between BS and MS. Relevant topics for these cases are:

- 1) The power control mechanisms which adjust the output level of the mobile station (and optionally of the base station) in order to ensure that the required quality is achieved with the less possible radiated power. Power levels with 2 dB steps have been defined for that purpose. This is described in 3GPP TS 45.008 and 3GPP TS 45.005.
- 2) The synchronization of the receiver with regard to frequency and time (time acquisition and time frame alignment). The synchronization problems are described in 3GPP TS 45.010.
- 3) The hand-over and quality monitoring which are necessary to allow a mobile to continue a call during a change of physical channel. This can occur either because of degradation of the quality of the current serving channel, or because of the availability of another channel which can allow communication at a lower Tx power level, or to prevent a MS from grossly exceeding the planned cell boundaries. In the case of duplex point-to-point connections, the choice of the new channel is done by the network (base station control and MSC) based on measurements (on its own and on adjacent base stations) that are sent on a continuous basis by the mobile station via the SACCHs. The requirements are specified in 3GPP TS 45.008.
- 4) The measurements and sub-procedures used in the first selection or reselection of a base station by a mobile are specified in 3GPP TS 45.008. The overall selection and reselection procedures, together with the idle mode activities of a mobile are defined in 3GPP TS 43.022.
- 5) The measurements and sub-procedures used by an MS in selecting a base station for reception of a voice group or a voice broadcast call are specified in 3GPP TS 45.008. The overall voice group and voice broadcast cell change procedures, being similar to the reselection procedures related to the idle mode activities of an MS, are defined in 3GPP TS 43.022.
- 6) For the adaptive speech traffic channels the inband signalling carries the required information to adapt the speech and channel codec modes to the propagation conditions. The coding of the in band signalling is specified in 3GPP TS 45.009. An example of codec adaptation algorithm is also provided in 3GPP TS 45.009.

11 Performance

Under typical urban fading conditions (i.e. multipath delays no greater than 5 μ s), the quality threshold for full-rate speech and PDTCH/CS1 is reached at a C/I value of approximately 9 dB. The maximum sensitivity is approximately -104 dBm for base stations and GSM mobiles and -102 dBm for GSM small MSs and PCS 1900 MSs and -100 dBm for DCS 1 800 hand-helds (see 3GPP TS 45.005).

Multi band MSs shall meet the requirements on each band of operation respectively.

12 Flexible layer one

With the Flexible Layer One (FLO), the physical layer offers transport channels to the MAC sublayer of Layer 2 (see 3GPP TR 45.902). Figure 4 shows the radio interface protocol architecture around FLO. On transport channels, transport blocks (TB) are exchanged between the MAC sublayer and the physical layer on a Transmission Time Interval basis (TTI). A transport channel is characterized by how the information is transferred over the radio interface. FLO is configured by Layer 3.

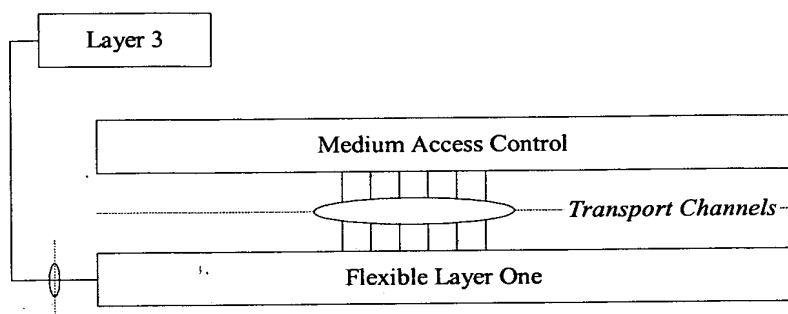


Figure 4: Radio interface protocol architecture around the physical layer for FLO

In the following subclauses, the new concepts and definitions introduced by FLO are explained. The multiple access and timeslot structure of section 5, the frequency hopping capability of section 6, the modulations of section 8, the transmission and reception of section 9, and the other layer 1 functions of section 10 remain unchanged and can be used as such by FLO.

12.1 Set of transport channels

The offered transport channels are Dedicated CHannels (DCH). A DCH can be either full rate (DCH/F) or half rate (DCH/H) depending on the rate of the dedicated basic physical subchannel on which they are used.

12.2 Transport block structure

A summarised description of the transport block structure for FLO appears in table 2, in terms of net bit rate, length and recurrence of blocks.

Table 2: Transport block structures

Type of transport channel	net bit rate (kbit/s)	block length (bits)	block recurrence (ms) ¹
DCH/F	0,05 - 68,5	1 - 1370	20
DCH/H	0,05 - 34,1	1 - 682	20

NOTE 1: or transmission time interval (TTI).

12.3 Channel organisation

The channel organization for FLO uses the 26-frame multiframe structure, as described in figure 2 of section 5.3, where T depicts a TDMA frame that can be used to transmit transport block(s).

12.4 Transport channel coding/multiplexing for FLO

The coding/multiplexing unit of FLO is a combination of error detection, forward error correction, rate matching, multiplexing and interleaving.

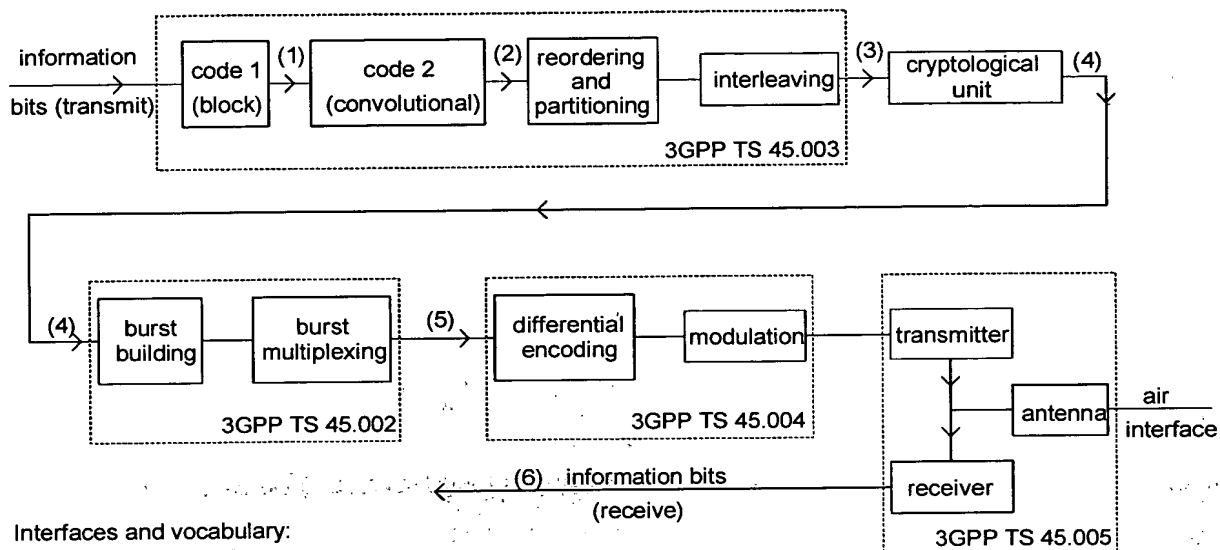
The transport channels offered by FLO (DCHs) are used to transmit data flows with a negotiated QoS over the radio interface. A number of transport channels can be active at the same time and multiplexed at the physical layer. The configuration of a transport channel is denoted the Transport Format (TF). A number of different transport formats can be associated to one transport channel. Layer 3 controls the configuration of the transport formats. Only a limited number of combinations of the transport formats of the different TrCHs are allowed. A valid combination is called a Transport Format Combination (TFC). The set of valid TFCs is called the Transport Format Combination Set (TFCS). In every radio packet, the Transport Format Combination Indicator (TFCI) tells which TFC is used. The following coding/multiplexing steps can be identified:

- CRC attachment: error detection is provided on each transport block through a cyclic redundancy check (CRC). Layer 3 configures the size of the CRC to be used. Code blocks are output from the CRC attachment.
- Channel coding: after CRC attachment, the code blocks are processed through channel coding (1/3 rate convolutional code), producing encoded blocks.
- Rate matching: in rate matching, bits of an encoded block on a transport channel are repeated or punctured to ensure that the total bit rate after TrCH multiplexing is identical to the total channel bit rate of the allocated basic physical channel. Outputs from the rate matching are called radio frames. The rate matching produces one radio frame per encoded block, i.e. per TrCH.
- Multiplexing of transport channels: for every radio packet to be transmitted, one radio frame from each TrCH is delivered to the TrCH multiplexing. These radio frames are serially multiplexed into a Coded Composite Transport CHannel (CCTrCH).

TFCI:mapping: the coded TFCI is appended at the beginning of the CCTrCH to form a radio packet.

- Interleaving: the radio packet is interleaved and then mapped on bursts. The interleaving can be either block diagonal or block rectangular and is configured by Layer 3.

Annex A (informative): Reference configuration

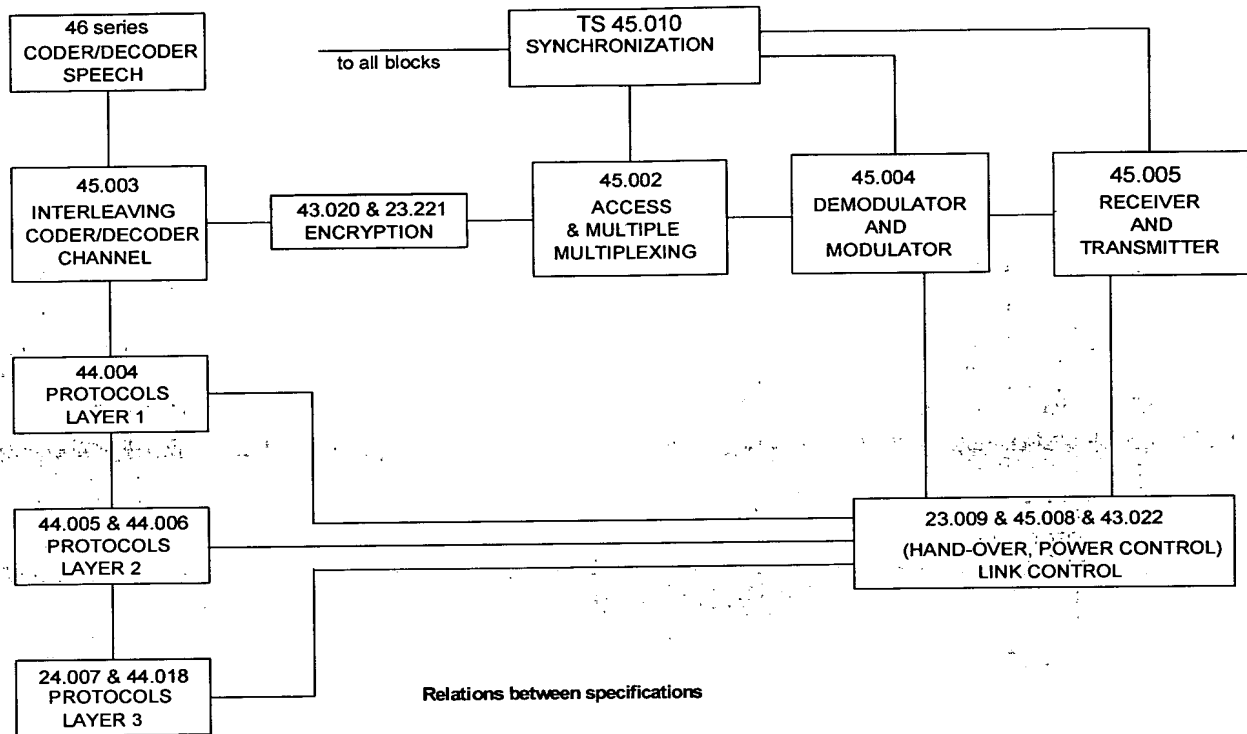


Interfaces and vocabulary:

- (1) info + parity bits
- (2) coded bits
- (3) interleaved bits
- (4) encrypted bits
- (5) modulating bits
- (6) information bits (receive)

REFERENCE CONFIGURATION

Annex B (informative): Relations between specification



Annex C (informative): Change history

SPEC	SMG#	CR	PHASE	VERS	NEW_VERS	SUBJECT
05.01	S18	A005	2+	4.6.0	5.0.0	Addition of ASCII features
05.01	S20	A006	2+	5.0.0	5.1.0	Introduction of high speed circuit switched data
05.01	s21	A007	2+	5.1.0	5.2.0	Introduction of R-GSM band
05.01	s22	A009	2+	5.2.0	5.3.0	Clarification of the frequency definition text in section 9
05.01	s24	A010	R97	5.3.0	6.0.0	Introduction of GPRS
05.01	s25	A012	R97	6.0.0	6.1.0	14.4kbps Data Service
05.01	s25	A013	R97	6.0.0	6.1.0	Renaming of GPRS RR states
05.01	s28	A014	R98	6.1.1	7.0.0	Harmonization between GSM and PCS 1900 standard
05.01	s28	A015	R98	6.1.1	7.0.0	Introduction of CTS in 05.01
05.01	s28	A016	R98	6.1.1	7.0.0	Introduction of AMR in 05.01
05.01	s29	A017	R99	7.0.0	8.0.0	Introduction of GSM 400 in 05.01
05.01	s29	A018	R99	7.0.0	8.0.0	05.01 changes for ECSD FACCH
05.01	s30	A020	R99	8.0.1	8.1.0	Correction of AMR Block Structure Parameters, Introduction of TCH/EFS
05.01	s30	A021	R99	8.0.1	8.1.0	Introduction of the definition of the PDTCH for EGPRS
05.01	s30	A022	R99	8.0.1	8.1.0	EDGE Compact logical channels
05.01	s30b	A023	R99	8.1.0	8.2.0	Support of Slow Frequency Hopping for EGPRS COMPACT
05.01	s31	A024	R99	8.2.0	8.3.0	Complete Frequency Hopping on COMPACT
05.01	s32	A026	R99	8.3.0	8.4.0	Definition of PDCH/H and alignment with DTM
						September 2000 - 3GPP TSG-GERAN
05.01	G01	A028	R99	8.4.0	8.5.0	CR 05.01-A028 DTM (R99)
05.01	G01	A029	R99	8.4.0	8.5.0	CR 05.01-A029 DTM+EGPRS (R99)
05.01	G01	A031	R99	8.4.0	8.5.0	CR 05.01-A031 Minimum Mobile Station Class and Channelization Capabilities
GERAN						Release 4
05.01 / 45.001	G01	A030	Rel4	8.5.0	4.0.0	CR 05.01-A030 Introduction of GSM 700 (Release 4)
				4.0.0	4.0.1	Oct 2000: References corrected.

Change history							
Date	TSG GERAN#	TSG Doc.	CR	Rev	Subject/Comment	Old	New
2001-01	03	GP-010240	001		Introduction of Wideband AMR for GMSK modulated speech channel	4.0.1	5.0.0
2001-08	06	GP-011917	003	1	Introduction of EPC channels	5.0.0	5.1.0
2001-11	07	GP-012350	004		Introduction of adaptive half rate speech channels with 8-PSK modulation	5.1.0	5.2.0
2001-11	07	GP-012364	006		Correction of description Wideband AMR channel coding	5.1.0	5.2.0
2001-11	07	GP-012767	008	1	Correction of references to relevant 3GPP TSs	5.1.0	5.2.0
2001-11	07	GP-012509	010		Coding rate of MCS3	5.1.0	5.2.0
2002-04	09	GP-021168	012	1	Alignment of number of codecs for WB-AMR to proposed set	5.2.0	5.3.0
2002-04	09	GP-020885	013		Decimal Sign	5.2.0	5.3.0
2002-04	09	GP-021204	014	1	Introduction of AMR-WB on 8PSK modulated speech traffic channels	5.2.0	5.3.0
2002-06	10	GP-021434	016		Corrections and clean up	5.3.0	5.4.0
2002-06	10	GP-021629	018		Miscellaneous corrections	5.3.0	5.4.0
2002-11	12	GP-023113	020		CRC Sizes for AMR-WB	5.4.0	5.5.0
2002-11	12	GP-023321	019	2	Implementation of new frequency ranges	5.5.0	6.0.0
2003-04	14	GP-030986	023	1	MCS-3 padding for MCS-8 retransmission	6.0.0	6.1.0
2003-11	17	GP-032459	024	2	Flexible Layer One	6.1.0	6.2.0
2003-11	17	GP-032556	027		Correction due to change of DTM core capability	6.1.0	6.2.0
2004-02	18	GP-040362	028		Correction on MS support of EGPRS coding schemes	6.2.0	6.3.0
2004-06	20	GP-041231	030		Correction of Figure 2a1	6.3.0	6.4.0
2004-11	22	GP-042469	034		Introduction of MBMS	6.4.0	6.5.0
2004-11	22	GP-042785	035		Removal of PTM-M	6.4.0	6.5.0
2004-11	22	GP-042879	038	1	FLO-compatible quick fix for VT over GERAN	6.4.0	6.5.0
2005-04	24	GP-050779	042		Introduction of GSM 710	6.5.0	7.0.0
2005-06	25	GP-051714	043	1	Introduction of T-GSM 810	7.0.0	7.1.0
2005-11	27	GP-052846	0045	1	MBMS transfer mode	7.1.0	7.2.0

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